MATERNAL-NEONATAL HEALTH OUTCOMES, RISK AND RESILIENCE FOLLOWING HURRICANES IRMA AND MARIA IN THE US VIRGIN ISLANDS: A MIXED METHODS STUDY

by
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Abstract

Background: Hurricanes Irma and Maria struck the United States Virgin Islands (USVI) in September 2017 causing widespread destruction. The impact of these Hurricanes on adverse maternal and neonatal outcomes in the USVI is unknown.

Objective: The purpose of this dissertation was to understand the impact of Hurricanes Irma and Maria on adverse maternal and neonatal health and outcomes in the USVI**.** The two study aims were to: 1) examine the association between hurricane exposure and no prenatal care (NPC), hypertensive disorders of pregnancy (HDP), preterm birth (PTB), cesarean birth (CB), small for gestational age (SGA) and low birth weight (LBW); and 2) understand the experience of managing pregnancy and birth, including factors of risk and resilience, after hurricane exposure.

Methods: This was a convergent mixed methods study. The quantitative phase incorporated an interrupted time series analysis of USVI birth data. The qualitative phase included interviews with women (*N* = 18) who were pregnant during or within two months after the hurricanes. An adapted conceptual framework of risk and resilience guided this study.

Results: The USVI experienced a significant decrease in the trend of SGA (B=-0.347; *p* =.037) and an increase in the trend of PTB (B= 0.364; *p* =.004) in the post-hurricanes period. There was no change in the level or trend in the rates of HDP, CB, and LBW. The qualitative phase revealed themes detailing risk factors including poor nutrition,

stress, lack of support, physical/environmental hazards, and negative impacts on ambulatory and inpatient maternity care. Themes of resilience emerged as personal coping strategies, abundant support, and the continuity of high-quality maternity care. Women with high-risk pregnancies reported that their maternity providers recommended relocation to the mainland US, likely driving the decrease in trend of SGA. Stress characterized women's experiences, potentially contributing to the increase in trend of PTB.

Conclusion: It is vital that maternity providers, departments of health, and hospitals understand the potential maternal-neonatal health effects of hurricane exposure. Collaborative hurricane preparedness and response plans and policies should focus on providing anticipatory guidance, maintaining continuity of prenatal care, mental health support, and relocation assistance to women experiencing high-risk pregnancies.

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Dedication

This manuscript is dedicated to:

The people of the US Virgin Islands.
Thank you for allowing me to tell one part of your story.

Baby X: I can't wait to meet you.

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CHAPTER 1: INTRODUCTION

Background and Rationale

Two category 5 hurricanes made landfall in the US Virgin Islands (USVI) in September 2017.[1] Hurricane Irma hit St. Thomas and St. John on September 6th and Hurricane Maria hit St. Croix on September 20th.[1] Through widespread flooding and destructive winds, these hurricanes compromised the territory's clean water sources, electricity, food supply, housing, education, and health services.[1] Evidence from several large, population-based studies conducted in the United States suggests that pregnant women and newborns may be disproportionately affected by hurricane-related stressors, including diminished prenatal and healthcare services,[1,2] disrupted social service programs,[1,3] interrupted access to nutrition,[1,4,5] loss of housing,[1,6] forced displacement,[1,7,8] and significant job loss and acute socioeconomic decline.[1,9] The hurricanes were directly responsible for five deaths.[1] However, as research estimates of excess deaths after Hurricane Maria in Puerto Rico have shown, measuring a hurricane's direct and indirect health impact is a complex and multi-faceted task.[10] Similarly, understanding the hurricanes' population- and individual-level impact on maternal and neonatal health and outcomes in the USVI requires a multi-pronged approach.

Markers of socioeconomic disparity indicate that the USVI was particularly vulnerable to the catastrophic structural and community damage caused by the hurricanes. Pre-existing socioeconomic disparities may have further complicated post-hurricane maternal and neonatal health outcomes. The USVI is a rural population comprising 78% African Caribbean (AC)/Black, 17.45% Latino and 15.6% white

people.[11] Twenty-two percent of USVI AC/Blacks and 32.8% of USVI Latinos of any race live below the poverty line, rates which are on par with or worse than those of Blacks (22%) and Latinos (18.3%) in the United States.[11,12] The complex intersections of pregnancy, hurricane damage and stress, and socioeconomic disparity suggest that interrelated biological, environmental, structural and health-system effects may influence post-hurricane maternal and neonatal vulnerability. Although maternal and neonatal outcomes such as preterm birth and cesarean delivery (7.3% and 26.4%) for USVI Blacks are lower when compared to US blacks (13.8% and 35.9%),[13] it is imperative to know how maternal and neonatal outcomes are impacted after widespread catastrophic hurricane damage among a population experiencing socioeconomic disparity.

As meteorologists project an increasing incidence of severe hurricanes, there is a growing and urgent need to understand how hurricanes affect maternal and neonatal outcomes.[14] The USVI are vulnerable to cyclical damage from major hurricanes, on average, every 6 years.[1] Since 1981, the maximum wind speed of hurricanes has steadily increased,[15] and there has been a measurable surge in the frequency, duration, and intensity of category 4 and category 5 hurricanes.[14,16] Meteorologists forecast that North Atlantic hurricanes will increase in severity and frequency, indicating that this potentially destructive cycle may continue to worsen.[14]

In addition to healthcare and systemic effects, hurricane-related stressors may cause physiologic changes that affect maternal and neonatal outcomes. Stress is associated with neuroendocrine changes and immune dysregulation.[17,18] Researchers have theorized that chronic stress, life events, and cumulative socioeconomic

disadvantage produce an increase in poor obstetric outcomes like preterm birth and low birth weight among Black women.[19–21] Hurricanes may cause similar stress-induced physiologic and biobehavioral process changes that may increase risk of adverse maternal and neonatal outcomes. Hurricanes can also impact maternal and neonatal care utilization by diminishing health system capacity and preventing access to routine and emergent obstetric care.[7,22] High quality and large-scale research studies based on vital statistics data demonstrate that indicators of medical care quality, access, and utilization—such as rates of cesarean delivery and insufficient prenatal care—increased after hurricanes.[23,24]

The sparse literature examining the impact of hurricane exposure on maternal and neonatal health has not yet addressed US territories in the Caribbean, despite their geographical vulnerability to cyclical hurricane damage. Researchers have identified that maternal and neonatal health outcomes, such as increased rates of cesarean deliveries and insufficient prenatal care, are potential outcomes of hurricane exposure.[23–25] In the 12 months after Hurricane Katrina, rates of cesarean delivery in Gulf Coast states rose as much as 6-10%.[23,24] The incidence of insufficient prenatal care also increased significantly, with disproportionate ethnic group effects.[23,24] Non-Hispanic Black women and Hispanic women experienced larger increases in insufficient prenatal care than non-Hispanic white women.[23] Disaster-compromised health systems and diminished healthcare access may impact the continuity of prenatal and obstetric care, as well as the response to maternal and neonatal complications.[22]

Extant research lacks thorough examination of maternal and neonatal outcomes such as hypertensive disorders during pregnancy and infants born small for gestational

age. An integrative review found that other variables, such as low birth weight, have yielded inconsistent findings, possibly due to hurricane heterogeneity, differences in local populations, confounding from displacement and migration, and methodological differences in how hurricane exposure is defined (N. Jeffers and N. Glass, unpublished data, 2020). Experiencing hurricane-related injury is associated with preterm birth; having three or more severe hurricane experiences—such as walking through floodwaters, feeling that one's life was in danger, or having a loved one die—is associated with a 5-fold increase in preterm birth.[26] Stress and associated biobehavioral pathways may contribute to these outcomes.[7,27,28] While existing qualitative research has described the experience of managing pregnancy in hurricanes, researchers have not yet attempted to understand the factors that contribute to high levels of risk or resilience in the context of actual population-level outcomes.[29]

Further, there are no published studies focusing on maternal and neonatal health outcomes for minorities after hurricanes that integrate population-level pregnancy, birth, and neonatal outcome data with qualitative descriptive data on risk and resiliency. To address this gap in extant knowledge, this study's convergent, mixed methods design will not only quantitatively describe the effects of hurricanes on maternal and neonatal health outcomes but also provide descriptive insight into factors of risk and resilience that may influence maternal and neonatal outcomes. The mixed methods approach will enable me to address the individual, household/community, and health care system domains of influence on maternal and neonatal health after hurricane exposure in the USVI.

Purpose

The overall purpose of the study is to understand the impact of Hurricanes Irma and Maria on maternal and neonatal health and outcomes in the USVI on a population and individual level. This convergent mixed methods study will 1) examine the association between hurricane exposure and maternal and neonatal health and outcomes; and 2) increase understanding of the experience of managing a pregnancy and birth within the context of hurricane exposure, including factors of risk and resiliency. The study will incorporate two simultaneous phases: a quantitative phase and a qualitative phase. The goal of the quantitative phase is to examine the population-level change in trend of adverse maternal and neonatal outcomes after Hurricanes Irma and Maria. An interrupted time series analysis with autoregressive regression models will be applied to de-identified aggregate birth data supplied by the USVI Department of Health. The goal of the qualitative phase will be to identify and explore, through in-depth interviews, markers of high risk and resilience that may explain vulnerability to or protection against adverse maternal and neonatal outcomes.

Specific Aims

The following 2 specific aims are proposed:

Aim 1 (Quantitative): Examine if the pattern of adverse maternal and neonatal outcomes in the USVI changed after severe hurricane exposure by conducting an interrupted time series regression analysis of aggregate birth data from the USVI Department of Health.

Hypothesis 1: The level and trend of no prenatal care, hypertensive disorders of pregnancy, preterm birth, cesarean delivery, small for gestational age newborns, and low birth weight will increase in the post-hurricanes period as compared to the pre-hurricanes period.

Aim 2 (Qualitative and Mixed Methods):

2a. (Qualitative). Among women who were pregnant during Hurricanes Irma and Maria**,** explore individual experiences of managing pregnancy and giving birth in the months after the hurricanes.

The following topics will be explored through in-depth interviews with 18-20 women:

(1) Hurricane-related deficiencies in prenatal or obstetric care access, utilization, and quality that are known contributors to adverse maternal and neonatal outcomes.

(2) Individual, interpersonal, community, health system, societal, and structural factors that contributed to maternal and neonatal health risk and resiliency.

2b. (Mixed Methods). Understand the pattern of maternal and neonatal outcomes after severe hurricane exposure within the context of in-depth descriptions of risk and resilience.

Conceptual Framework

The proposed study is guided by an adapted conceptual framework for maternal-neonatal health, risk, and resilience following hurricane exposure. The original framework is the UNICEF Conceptual Framework for Maternal and Neonatal Morbidity and Mortality (see Figure 1).[30] This framework was designed to assist organizations and

health systems with 1) assessing and analyzing causes of maternal and newborn mortality and morbidity and 2) improving maternal and neonatal health.[30] The framework is primarily organized according to Bronfenbrenner's socioecological model;[31,32] the causes of maternal and neonatal morbidity and mortality fall into three levels: direct, underlying, and structural. Direct causes may include congenital factors, obstetric complications, diseases and infections, and inadequate dietary intake. Other underlying causes may include lack of access to routine and emergent maternal-neonatal health services, inadequate access to food, poor water and sanitation, and lack of education and health literacy. Finally, structural causes of adverse outcomes include the overall quantity and quality of resources for maternal-neonatal health; the political, social, and economic context affecting the community; and the prevailing beliefs and systems that impact women's healthcare services. Each level is interrelated as opposed to solitary, potentially impacting those above and below it.[30]

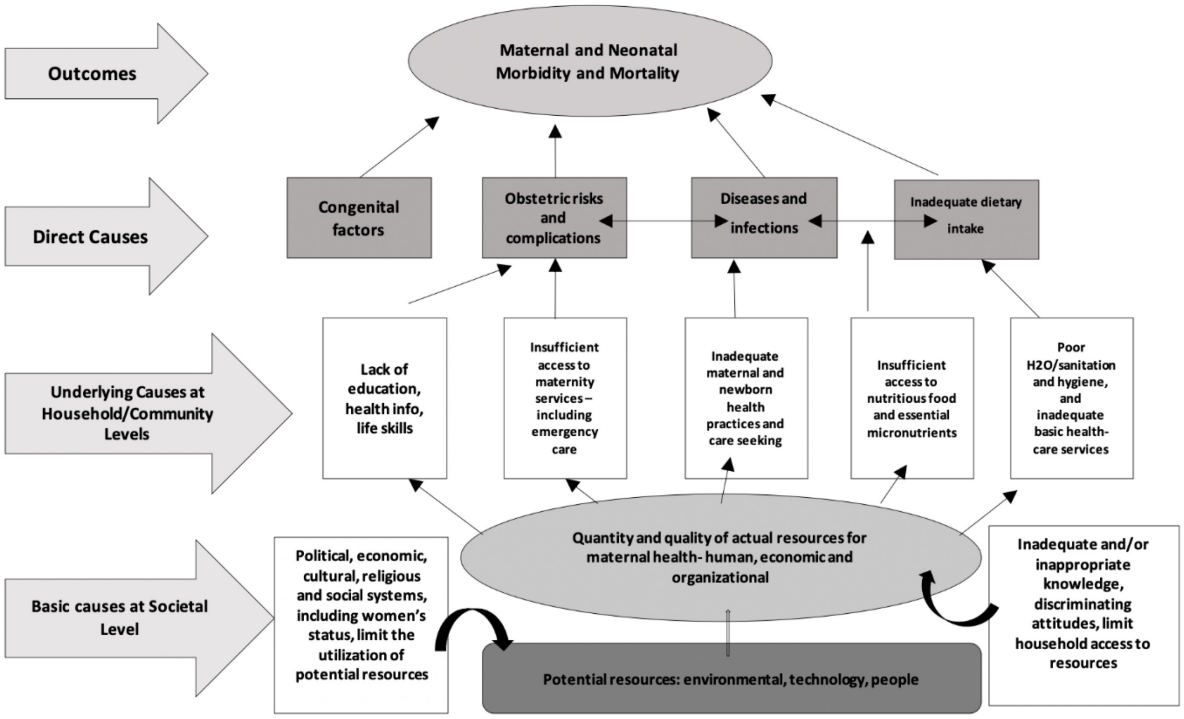

Figure 1. UNICEF Conceptual Framework for Maternal and Neonatal Morbidity and Mortality

In the adapted framework (see Figure 2.), there are several key modifications. I posit the framework within the context of hurricane exposure and consider the basic, direct, and societal level cause of maternal-neonatal morbidity and mortality within three new levels: individual, household/community, and societal/system. Components of risk and resilience related to maternal-neonatal health arise from each level. The adapted framework incorporates additional sources of risk that may be associated with hurricane exposure. Each of these components (hurricane exposure, risk, and resilience), interact to influence maternal and neonatal outcomes.[30] For the purposes of this dissertation, the societal/systems level focuses on the USVI maternity system.

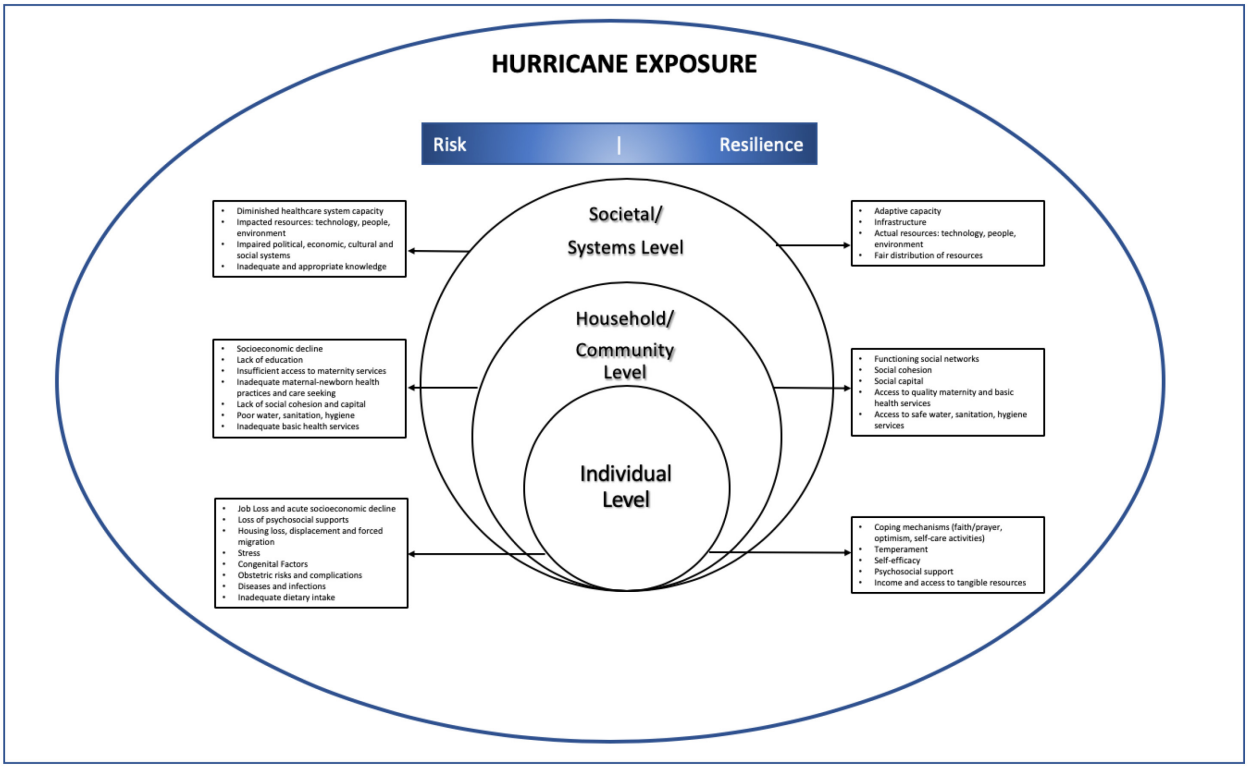

Figure 2. Adapted Conceptual Framework for Maternal-Neonatal Health, Risk and Resilience following Hurricane Exposure

Hurricane Exposure

For the qualitative phase of this dissertation, hurricane exposure is defined as those who were living in the US Virgin Islands when Hurricane Irma and Maria hit. For the quantitative phase, the post-hurricanes time period includes any births that occurred between October 2017 and June 2019.

Risk and Resilience

Risk is defined as causes of and contributors to maternal and neonatal morbidity and mortality.[30]

Resilience is conceptually defined as "the capacity of a dynamic system to adapt successfully to disturbances that threaten the viability, the function, or the development of that system."[33] In this dissertation, a "system" is interpreted as the overarching applies to individuals, households/communities, and society/systems.

Maternal and Neonatal Health Outcomes

The quantitative phase of this study examines the longitudinal effects of hurricane exposure on 6 key maternal and neonatal health outcomes. *No prenatal care* is defined as a case in which someone did not initiate prenatal care. *Hypertensive disorders of pregnancy* are a group of diseases including preeclampsia, eclampsia, gestational hypertension, and chronic hypertension. *Preterm birth* are births that occur between 24 weeks and 0 days and 36 weeks and 6 days. *Cesarean birth* is a surgical procedure to deliver a baby through incisions in the abdomen and uterus. *Low birth weight* is defined as births in which the newborn weighs less than 2500 grams. *Small for*

gestational age includes newborns who are <10% of the expected weight for their established gestational age.

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CHAPTER 2: MANUSCRIPT ONE

Integrative Review of Pregnancy and Birth Outcomes following Exposure to a Hurricane

Integrative Review of Pregnancy and Birth Outcomes following Exposure to a Hurricane

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Abstract

Objective: To review the literature on the effects of exposure to hurricanes on pregnancy and birth outcomes.

Data Sources: A literature search was conducted in four electronic databases: CINAHL Plus, Embase, PubMed, and Web of Science. The following search terms were used: *cyclonic storms, cesarean section, premature birth, fetal mortality, low birth weight, infant mortality, pregnancy complications,* and *pregnancy outcome*.

Study Selection: Inclusion criteria were peer-reviewed, full-text articles or government documents published in English from journal inception through February 2020 that focused on the associations between exposure to hurricanes and adverse pregnancy and birth outcomes. The initial database search yielded 211 articles and 1 article was identified through a hand search. After 48 duplicates were removed, the titles and abstracts of 164 articles were screened. Authors conducted a full-text review of 57 articles and 19 articles were included in the integrative review.

Data Extraction: Data from the full-text of each article was extracted into a standardized table with the following headings: author, study design, year of publication, location, hurricane and year, population studied, outcomes, data source, and results.

Data Synthesis: We analyzed study findings based on the outcomes of pregnancy complications, preterm birth, cesarean birth, labor and birth complications, low birth weight, abnormal newborn conditions, and fetal mortality. Data were synthesized in a narrative format. The synthesis indicated that hurricane exposure was frequently associated with pregnancy complications, preterm birth, low birth weight, cesarean birth, and abnormal newborn conditions. However, these associations were not always consistent. Existing research is limited by inconsistency among study designs and the method of defining hurricane exposure.

Conclusion: Interdisciplinary teams that include nurses, midwives, obstetricians and gynecologists, and other healthcare professionals should ensure that hurricane preparedness and response efforts specifically address the needs of pregnant women to mitigate adverse outcomes.

Keywords: cyclonic storm, cesarean section, premature birth, fetal mortality, infant, low birth weight, infant mortality, pregnancy complications, pregnancy outcome

Pr´ecis: Hurricane exposure is associated with pregnancy complications, preterm birth, cesarean birth, labor and birth complications, and abnormal newborn conditions.

Introduction

Pregnant women are vulnerable to the multiple, inter-related structural, economic, health, and social effects of hurricanes. The most severe hurricanes can lead to sudden interruption of access to prenatal care,[1] multiple hospital evacuations,[2] health professional burnout,[3] and migration of the healthcare workforce,[4] which potentially compromise the capacity of the health system. Food insecurity,[5] as well as exposure to infectious disease and environmental toxins,[6] potentially increase the risk for pregnancy complications, infection, and congenital defects.

Pregnant women must also cope with other hurricane-related stressors that are commonly experienced by the general population, such as displacement and forced migration,[7] loss of tangible resources or psychosocial support,[8] housing instability,[9] and sudden employment loss or income decline.[10] These stressors often have health-related effects. For example, after Hurricane Katrina, individuals who experienced acute changes in income or resources were more likely to experience long-term health complications such as chronic pain, heart attack, and stroke.[10] While a hurricane is usually only a one-day event, the intersecting, long-term effects can be far-reaching. Moreover, disaster effects are often disproportionately experienced among disadvantaged populations. For example, Black residents in Louisiana were more likely to report long-term negative effects of Hurricane Katrina on their finances, their health, and their emotional well-being than white residents.[11]

Understanding the experience of hurricane-related stress during pregnancy is important because maternal psychosocial stress has been linked to preterm birth and low birth weight.[12,13] Exposure to serious life events[14] and other natural disasters such

as floods[15] are positively associated with increased rates of preterm birth and low birth weight. Maternal stress is associated with neuroendocrine changes and immune dysregulation, which are hypothesized to prematurely provoke the initiation of the parturition pathway,[16] increasing the risk of preterm birth and low birth weight.[17]

The Saffir Simpson Hurricane Wind Scale characterizes Atlantic, Eastern Pacific, and Central Pacific hurricanes according to wind intensity and damage potential to structures and communities.[18] Meteorologists categorize hurricanes into 5 ascending categories, from 1 to 5. Category 1 hurricanes are very dangerous, with sustained wind speeds between 74-96 miles per hour (mph). Category 2 hurricanes are extremely dangerous hurricanes with sustained wind speeds between 96-110 mph. Category 3 hurricanes will cause devastating damage with sustained wind speeds between 111-129 mph. Category 4 and 5 hurricanes are major hurricanes and both have the potential to cause catastrophic damage and loss of life. These hurricanes have sustained wind speeds of 130-156 mph or 157 mph or higher, respectively. Hurricanes in other regions are called cyclones or typhoons and are measured on a variety of tropical cyclone intensity scales by regional agencies.[18]

Estimating the health effects of hurricanes, including those related to maternal, fetal, and neonatal health, continues to become more significant, as climate change models project that the most severe hurricanes, Category 4 and 5 storms, will increase in frequency.[19,20] Hurricane intensity depends on sea temperatures and atmospheric temperatures.[19] Rising temperatures, caused by both natural processes and human-induced changes, may contribute to more intense cyclonic storms.[19,20] The human expansion of the greenhouse effect on global warming may explain the increased

intensity of super storms and their associated consequences, such as heavy precipitation and coastal flooding.[21] These hurricane projections appear to be consistent with the unprecedented damage caused by recent Category 4 and 5 storms including Hurricane Katrina in 2005, Hurricane Sandy in 2012, Hurricanes Harvey, Irma, Maria, and Nate in 2017, Hurricane Florence in 2018, and Hurricane Dorian in 2019.

We were unable to identify any published scoping, integrative, or systematic reviews whose primary objective was to evaluate the associations between hurricane exposure and pregnancy and birth outcomes. Previous researchers conducted a systematic review of the perinatal health effects of a wide variety of disasters, including terrorist attacks, floods, hurricanes, earthquakes, and environmental disasters.[22] These researchers evaluated 8 hurricane-related studies. However, all but 1 of those studies focused solely on perinatal outcomes after Hurricane Katrina. Another group of researchers conducted a systematic review of the population health effects of climate change-related water events, including hurricanes, sea level rise, and floods.[23] The authors suggested that climate change initiates a cascade of environmental effects that affect population health by disturbing the health system infrastructure, triggering the release of toxins and infectious vectors, and interrupting access to clean water and food. That systematic review included only one study focused on pregnancy and birth outcomes after Hurricane Katrina. The focus of our integrative review will address some of the limitations of these prior reviews by including studies from multiple hurricanes that occurred in the United States and internationally in Australia and Vanuatu.

Given the risks posed by hurricanes to pregnant women and their infants across the globe; the known association between stress and adverse maternal-neonatal

outcomes; and growing projections of increasingly frequent and severe hurricanes, it is important to clarify the effects of hurricane exposure on pregnancy and birth outcomes. Therefore, the purpose of our review was to appraise and analyze published research on the relationships between hurricane exposure and adverse pregnancy and birth outcomes.

Methods

We utilized the five stages of integrative review methodology proposed by Whittemore and Knafl.[24] Studies were eligible if they met the following criteria: (1) clearly delineated relationships between hurricane exposure and pregnancy and birth outcomes and (2) published as a peer-reviewed English language journal article or a government publication with full text available. Conference abstracts and studies published in languages other than English were excluded. Articles were also excluded if they did not evaluate outcomes associated with pregnancy or birth. Postpartum outcomes were not evaluated in this study. With the assistance of a university librarian, a preliminary search of PubMed was conducted to identify optimal search terms, including: *cyclonic storm, hurricane, typhoon, tropical storm, premature birth, premature labor, cesarean section, stillbirth, fetal demise, infant, low birth weight, maternal mortality, infant mortality, pregnancy complications,* and *pregnancy outcome.* A comprehensive search was conducted using four databases: CINAHL Plus, Embase, PubMed, and Web of Science. We included articles published from journal inception through February 2020.

Data Extraction

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart documents the search strategy and selection of articles (described in Figure 3).[25] The initial search yielded a total of 211 records. To ensure that we did not overlook relevant studies, we then conducted a hand search and identified 1 additional article. We removed 48 duplicates and independently screened the titles and abstracts of 164 articles. We reviewed the full-text of 57 studies for inclusion. The final analysis included a total of 19 articles.

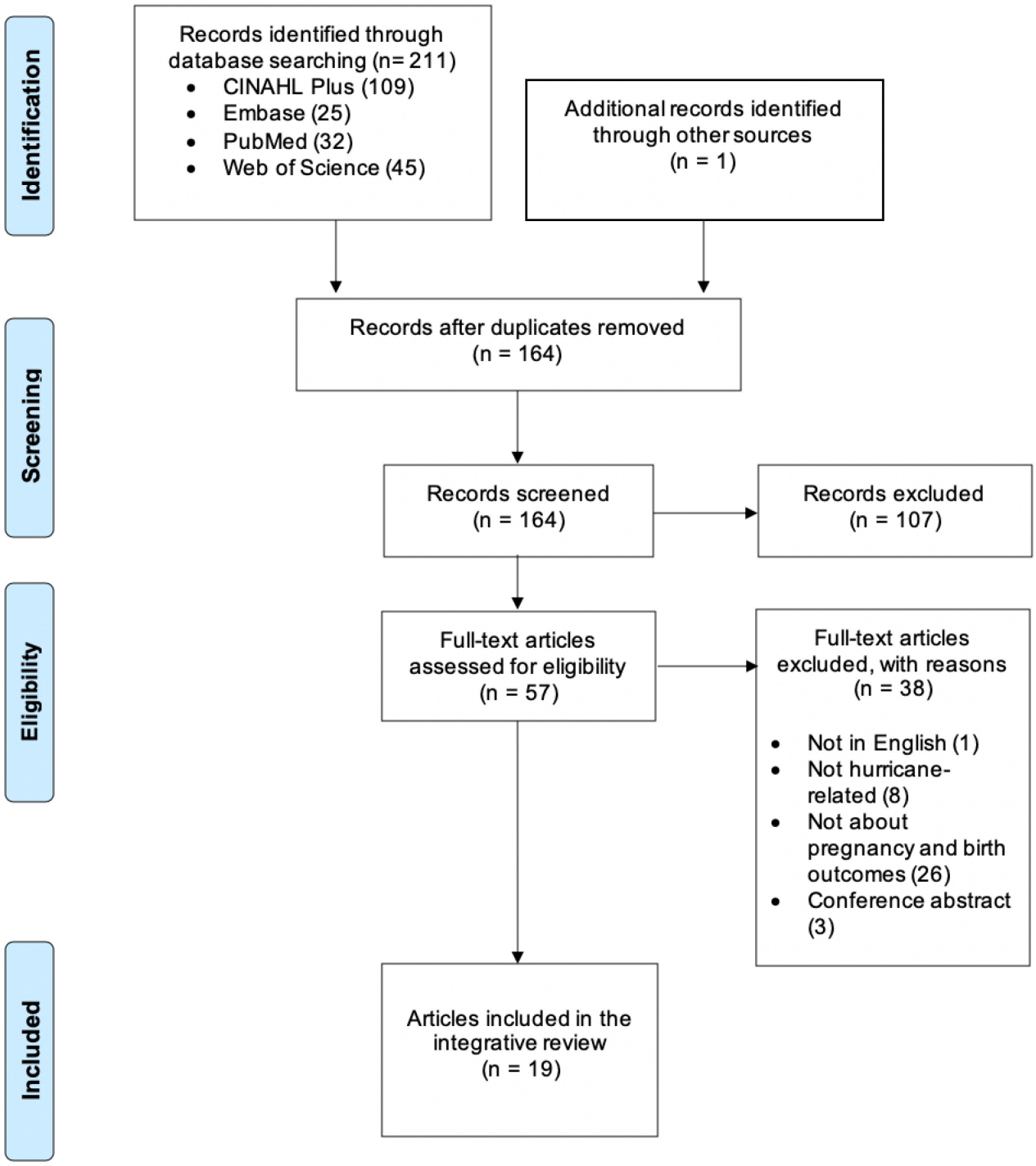

Figure 3. PRISMA Flow Chart of Search Strategy

Assessment of Methodological Quality

We evaluated the methodologic quality of the selected studies based on the critical appraisal checklists developed by the Joanna Briggs Institute.[26] The appropriate critical appraisal checklists were used depending on the design of each study evaluated: cross-sectional, cohort, or quasi-experimental. We appraised each of the selected studies independently for risk of bias. Studies achieved a range of quality scores between 66.7% and 100%, and decisions for inclusion were made by consensus. All 19 studies were retained.

Data Synthesis

Each author read the full text of the 19 included studies. The first author (N. J.) used a standardized extraction form to extract data related to author, year of publication, hurricane, study design, population studied, outcomes, hurricane exposure measure, data source, and results. We discussed the findings and agreed on the synthesis and analysis.

Results

Description of Included Studies

The characteristics of the 19 studies are provided in Table 1. Seventeen studies were conducted over a period of 11 years in the United States: Alabama, Louisiana, and Mississippi,[27,28] Florida,[29–32] Texas,[33,34] Florida and Mississippi,[35] Louisiana,[36–42] and New York.[43] Two studies were conducted internationally, in Australia[44] and Vanuatu.[45] The sample size studied ranged from 70[45] to 4,237,494.[33] Researchers in one study excluded participants younger than 16 years of age and older than 45 years of age.[29] In most studies, vital statistics were the primary data source.[28–33,35,36,38,41,42,44] Other data

sources included medical records review,[27,37,39,40,45] a perinatal hospital database,[34] and emergency department visit data.[43] Sixteen studies had retrospective designs and 3 were prospective.[37,39,40] The most common outcomes of interest included pregnancy complications, labor and birth complications, preterm birth, cesarean birth, abnormal newborn conditions, and low birth weight.

Hurricane Exposure Measurement

In the reviewed studies, authors used a variety of methods to define and measure hurricane exposure (see Table 2) and at times applied more than one measure. All methods are vulnerable to under- or over-estimation of any individual's exposure to hurricane, but some methods are more specific than others. In 2 studies, researchers utilized geo-referenced housing stock or property damage data to measure levels of hurricane exposure.[35,41] In 7 studies, the researchers used non-specific geographic markers of entire counties or states to identify hurricane-exposed individuals.[27,32,34,35,38,41,45] Researchers used nationally designated disaster areas to determine hurricane exposure in 4 articles.[28,30,43,44] In 5 studies, researchers defined hurricane exposure by identifying affected areas within a specified distance from the storm path.[28,30,33,35,36] Investigators in 3 studies used maximum wind-speed categories developed from the Saffir-Simpson Hurricane Wind Scale.[29–31]

Questions designed to describe and measure individual-level hurricane exposure were used in 5 studies.[34,37,39,40,45] Three studies [37,39,40] utilized a Hurricane Experience Scale adapted from a questionnaire used in the Social and Cultural Dynamics of Disaster Recovery study of Hurricane Andrew.[46] The authors in 1 of these 3 studies[37] organized the 11-item instrument into 3 categories of hurricane exposure measurement:

damage (damage to house, house flooded, impact of hurricane, total impact on other people); injury (experienced illness/injury, someone in household experienced illness, someone nearly died, someone else important experienced illness/injury); and danger (felt life in danger, walked in floodwater, saw someone die). Researchers categorized each item on a scale of ranging from low experience (0) to high experience (3 or 4).[37] Researchers in 2 studies used similar versions of the instrument, whereby exposure was evaluated by the number of discrete events an individual experienced and each event was weighted equally.[39,40] Researchers studying the effects of Hurricane Harvey asked women if they felt they were affected by the hurricane.[34] Researchers studying Cyclone Pam in Vanuatu evaluated hurricane exposure by asking a question to assess damage to the participant's neighborhood, house, and personal belongings. Researchers categorized responses from good, untouched by cyclone (1) to severe damage, must rebuild (4).[45]

Pregnancy Complications

Four groups of researchers investigated the relationship between hurricane exposure and pregnancy complications.[34,39,41,43] In the 3 months after Hurricane Sandy, researchers found that there was a 2.9% increase in emergency department visits for pregnancy complications (95% CI= [1.0%, 4.8%], p <.05).[43] Emergency department visits for gestational diabetes also increased by 42.3% in the first month after the hurricane (95% CI= [15.0%, 76.0%], p < .05). Seven months after Hurricane Sandy there was also a 21.9% increase in visits for gestational hypertension (95% CI= [6.4%, 39.7%], p <.05) and a 26.3% increase in visits for gestational diabetes or abnormal glucose tolerance (95% CI= [3.9%, 53.6%], p < .05). Researchers analyzing Hurricane

Harvey found that women who gave birth after Hurricane Harvey (*N* = 29,179) experienced increased rates of hypertensive disorders of pregnancy (aOR = 1.52, 95% CI= [1.30, 1.77], $p < .05$) when compared to women who gave birth before the Hurricane.[34] However, the authors of 1 prospective study (*N* = 220) found that hurricane exposure was not associated with either hypertension or gestational diabetes.[39] Researchers investigating lead concentrations in soil (*N* = 75,501), a known risk factor for preeclampsia and eclampsia, found that women residing in areas with higher deposits of lead after Hurricanes Katrina and Rita were up to 4 times (95% CI= [3.00,5.35], $p < .01$) more likely to experience an eclamptic event.[41]

Gestational Age and Preterm Birth

In 12 studies, researchers evaluated the relationship between hurricane exposure and gestational age or preterm birth.[27–30,33,34,36–38,40,43,44] Researchers in 5 studies found a positive association between hurricane exposure and preterm birth, defined as births that occur prior to 37 completed weeks gestation, or early onset of labor.[27,36,37,43,44] Both African-American (mean difference = 40.083, $p < .01$) and white women (mean difference = 36.946, $p < .01$) in the Gulf Coast (*N* = 81 counties) experienced an increase in preterm birth after Hurricane Katrina, although the effect was greater for African-American women.[27] The number and severity of hurricane experiences may be an important factor that explains the association between hurricane exposure and preterm birth.

Hurricane exposure may also have long-term effects on birth outcomes. Women surveyed 5-7 years after Hurricane Katrina (*N* = 308) and who experienced 1 or more episodes of injury during the hurricane had an increased rate of preterm birth (aOR =

5.22, 95% CI= [1.60, 17.06], $p < .01$).[37] Researchers studying Hurricane Andrew noted that hurricane exposure was associated with increased rates of preterm birth (N = 38,004, OR = 1.27, 95% CI= [1.12, 1.44]; X^2 = 13.8, $p < .001$).[36] Investigators of Cyclone Yasi also found that women in their first trimester who were living in affected areas (N = 311,389) also experienced increased rates of preterm birth (aOR = 1.26, 95% CI= [1.06, 1.49], $p < .05$).[44] After Hurricane Sandy, emergency department visits for evaluation of the early onset of labor increased by 115.9% (95% CI= [6.9%, 336.3%], $p < .05$).[43] In another study (N = 342,942, researchers found that Hurricane Charley was associated with extreme preterm birth, defined as birth occurring at less than 32 completed weeks gestation (aHR = 1.21; 95% CI= [1.06, 1.38], p value not provided).[29]

In 2 studies, researchers used different methods to define and measure hurricane exposure, which yielded different conclusions. The authors in 1 of these studies (N not specified) explored 8 different methods of measuring hurricane exposure for Hurricanes Charley, Ivan, Jeanne, and Frances and found that only 1 method yielded a positive association between hurricane exposure and preterm birth.[30] More specifically, exposure to Hurricane Ivan, when defined by the maximum recorded hurricane wind speeds, was positively associated with preterm birth (B = 0.03, p = 0.04). In the other large retrospective study (N = 4,237,494), authors explored 4 methods for measuring hurricane exposure, which yielded inconsistent and mixed associations.[33] They noted that their preferred estimate generated no significant associations. The authors of a prospective study (N = 301) reported that women who experienced 4 or more severe hurricane experiences had a nonsignificant increase in preterm birth.[40]

Researchers studying the perinatal health effects of Hurricane Harvey (*N* = 29,179) found no association between Hurricane Harvey and preterm birth.[34] The authors of 2 studies suggested that forced migration or births not captured in vital statistics records may explain negative associations between hurricane exposure and preterm birth. Researchers in 1 study (*N* = 254,665) reported that exposure to Hurricane Katrina in the hardest hit regions was not associated with preterm birth.[38] Non-Hispanic Black (aOR = .82, 95% CI [0.75, 0.88], $p < .01$) and Hispanic women (aOR = .72, 95% CI [0.57, 0.92], $p = .01$) in Region 1 of Louisiana, the region that experienced the most devastating damage, experienced a decrease in preterm birth rate.[38] Similarly, researchers in another study (*N* = 166,675) found that among regions that experienced the most damage, there was a 25% decrease in very preterm births—defined as births that occur prior to 32 weeks completed gestation—across all races and ethnicities.[28] Additionally, among non-Hispanic Black women, there was a 20% decrease in very preterm births. However, FEMA disaster-designated counties in Alabama—areas that received an influx of Louisiana residents after Hurricane Katrina—experienced a 21% increase in very preterm births. This finding supports the conclusion that forced migration of particularly vulnerable migrants resulted in a transfer of poor birth outcomes from Louisiana, the primary affected state, to the surrounding states.[28] This transfer of poor birth outcomes associated with population displacement was only seen among Black women: a population with pre-existing, race-based birth outcome disparities.

Labor and Birth Complications

Findings from 4 studies suggest that hurricane exposure is correlated with labor and birth complications. In a prospective cohort study (*N* = 220), the researchers found

exposure to stressful hurricane experiences to be associated with higher rates of induction of labor (aOR = 1.39; 95% CI [1.03, 1.86], $p = .03$).[39] Investigators of a large retrospective study ($N = 297,996$) reported that hurricane exposure in any trimester is associated with labor dystocia (B = 0.10, $p < .05$).[32] The authors of 1 study (N not specified) also noted that maternal exposure to Hurricane Andrew increased the odds of fetal distress in the second (*OR,* 1.20; 95% CI [1.08, 1.33], $p < .01$) and third trimester (*OR,* 1.26; 95% CI= [1.15, 1.38], $p < .01$).[35] African-American mothers exposed to Hurricane Andrew in the third trimester were at 1.46 times (95% CI = [1.26,1.70], $p < .01$) more likely to give birth to a newborn experiencing fetal distress than white women.

Cesarean Birth

Researchers evaluated the relationship between hurricane exposure and cesarean birth in 4 studies.[28,32,34,38] Scientists at the Centers for Disease Control and Prevention (CDC) found a 6% increase in cesarean birth rates after Hurricane Katrina ($N = 166,675$).[28] Similarly, authors of another large study in Louisiana ($N = 254,665$) found that the odds of cesarean birth increased significantly after Hurricane Katrina (aOR = 1.09, 95% CI [1.08, 1.11], $p < .01$).[38] Hurricane exposure was also significantly associated with cesarean birth in Florida after Hurricane Andrew ($N = 297,996$, B = 0.026, $p < .05$)[32] and in Texas after Hurricane Harvey ($N = 29,179$, aOR = 1.18, 95% CI [1.09, 1.28], $p < .05$).[34]

Birth Weight

The authors of 10 studies examined the relationship between hurricane exposure and birth weight.[27,28,30,31,33,36–38,40,44] Researchers in 6 of these studies found no association between hurricane exposure and low birth weight in the affected

areas.[28,31,33,36,37,44] In a small sample (*N* = 70) of women pregnant during Cyclone Pam in Vanuatu, birth weight was not found to be significantly associated with experiencing hardship (defined as damage incurred in the woman's village, home or garden).[45] The authors of 1 large study of Hurricane Katrina (*N* = 166,675) reported that areas with the most damage in Louisiana saw significant declines in the rate of low birth weight deliveries, while Alabama counties within a 100-mile radius of the storm path saw nonsignificant upward trends in low birth weight.[28] Although the upward trends in Alabama rates of low birth weight were nonsignificant, the findings again suggest that forced migration contributed to a decline in low birth weight rate in Louisiana, but an increase in the rate of low birth weight in surrounding areas.[28] Non-Hispanic Black women who were displaced to Alabama post-hurricane experienced a 35% increase in very low birth weight (defined as 1500 grams or less) deliveries, indicating a transfer of pre-existing birth disparities for Black women from Louisiana to Alabama.[28]

In contrast, investigators in 3 studies found consistent and significant associations between Hurricane Katrina exposure and low birth weight.[27,38,40] After Hurricane Katrina, researchers in 1 study found that African-American women in Alabama, Louisiana, and Mississippi experienced higher rates (mean difference = 29.014, $p < .001$) of low birth weight than white women.[27] Authors of a large, population-based study (*N* = 254,665) compared the 2 years pre-Katrina to the 2 years post-Katrina and identified a significant increase in low birth weight in Louisiana (aOR = 1.03, 95% CI [1.00, 1.06], $p = .04$).[38] Investigators using a prospective cohort design interviewed women (*N* = 301) in New Orleans. Participants who reported having 3 or more severe experiences with Hurricane Katrina (as described in the Hurricane Experience Scale;

see Table 1) were significantly more likely to give birth to a newborn with low birth weight (aOR = 3.3; 95% CI [1.13, 9.89]).[40] This finding was even more pronounced among women who had 4 or more severe hurricane experiences (*OR*, 5.5; 95% CI [1.19, 25.4]).

Findings from 1 study (*N* not specified) yielded inconsistent associations between hurricane exposure and low birth weight; the associations varied based on the method used to measure hurricane exposure.[30] The authors explored 8 methods of measuring hurricane exposure for 4 hurricanes and found that, overall, there was a negative association between hurricane exposure and low birth weight, but the association was not significant. Two methods investigators used to measure Hurricane Frances exposure resulted in a significant negative association with low birth weight. The two methods characterized hurricane exposure as occurring in counties that had experienced wind speeds greater than 39 miles per hour (B = −1.68, $p = 0.003$) or Category 2 level hurricane winds or higher (>95 miles per hour; B = -0.98, $p = 0.0007$).

Neonatal Outcomes

Researchers in 2 studies evaluated neonatal outcomes.[33,34] In the first study (*N* = 4,237,494), researchers indicated that hurricane exposure is associated with the presence of abnormal neonatal conditions.[33] The researchers of this study focused on establishing the effect of the trimester during which hurricane exposure occurred on conditions such as meconium aspiration and assisted ventilation. Meconium aspiration syndrome was found to be associated with hurricane exposure in the first (B = 0.0136, $p < .05$), second (B = 0.0326, $p < 0.0001$), and third trimesters (B = 0.0369, $p < 0.0001$). Hurricane exposure in the first (B = 0.0150, $p < .05$) and third (B = 0.0133, $p < .05$)

trimesters was associated with newborn assisted ventilation over 30 minutes; hurricane exposure in the second trimester was associated with assisted ventilation for any length of time (B = -0.0249, $p < .05$). When examining the relationship between Hurricane Harvey exposure and newborn arterial blood gas, researchers found a significant increase in newborns with arterial blood gas pH level less than 7.1 (OR = 2.42, 95% CI [1.67, 3.52]). Researchers analyzing post-hurricane birth outcomes in Texas reported that women exposed to hurricanes in the first trimester (B = 0.0165, $p < .05$) had higher odds of giving birth to a newborn with an arterial blood gas pH level less than 7.1.[34] Women who reported that they were affected by Hurricane Harvey were more likely to experience neonatal morbidity (aOR = 1.42, 95% CI [1.03, 1.94]), suspected or proven newborn seizure (OR = 17.1, 95% CI [1.55, 188.8]), and neonatal death (OR = 43.2, 95% CI [5.03, 370.6]).

Fetal Death

Researchers in 2 studies evaluated the association between hurricane exposure and fetal death, and produced conflicting results.[31,42] The authors of the first study (N = 382,700) found no association between hurricane exposure and fetal death after Hurricane Katrina.[31] However, researchers of a larger study of (N = 782,411) reported that Louisiana parishes with between 10-50% (aOR = 1.396; 95% CI [1.067, 1.827], $p < .05$) or greater than 50% (aOR = 2.367, 95% CI [1.684, 3.327], $p < .01$) of damaged housing stock after Hurricane Katrina experienced an increase in fetal death.[42] In that study, researchers identified a dose-response relationship: a 1% increase in housing stock destruction increased the odds of fetal death by 1.7% (aOR = 1.396, 95% CI [1.067, 1.827]), $p < .01$).

Discussion

In this integrative review, we synthesized evidence on the effect of hurricane exposure on adverse pregnancy and birth outcomes in 19 studies published over 11 years. This review adds to the existing literature by focusing specifically on the perinatal health effects of hurricanes. While past reviews have focused primarily on Hurricane Katrina, this review includes studies that evaluated a number of different hurricanes, both domestically and internationally. The two most common outcomes measured in the extant literature were preterm birth and low birth weight. Hurricane exposure was not consistently shown to be associated with low birth weight. Prior systematic reviews of natural disasters and low birth weight have shown similar results.[22,47] The findings from 5 out of 12 studies reviewed indicated that preterm birth was associated with hurricane exposure. Investigators of other natural disasters, such as floods and earthquakes, have also found both positive[15] and negative associations[48,49] between disaster exposure and preterm birth. Cesarean birth, although only examined in 4 studies, was consistently associated with hurricane exposure.[28,32,34,38] Several large studies noted that hurricanes may be associated with pregnancy diseases such as gestational diabetes and hypertensive disorders, abnormal newborn conditions, labor and birth complications, and other general pregnancy complications such as gestational diabetes and hypertensive disorders.[32,33,35,39,41–44] Importantly, few studies had examined each of these pregnancy-related disease outcomes in relation to hurricanes, indicating the need for future research including these understudied variables.

Studies in which researchers evaluated dose-response relationships between hurricane exposure and adverse outcomes resulted in positive associations. For

example, women with multiple severe experiences associated with the hurricane were more likely to give birth to an infant with low birth weight.[40] Women who experienced injury during a hurricane were more likely to experience preterm birth.[37] Additionally, findings from 2 studies indicated potential dose response relationships between hurricane damage and fetal death, cesarean birth, and labor dystocia.[32,35] These results suggest that future research is needed on the type, number and severity of hurricane exposures and adverse outcomes.

There was significant methodological heterogeneity among the studies evaluated. A key limitation of this integrative review is the inability to account for varied research designs, hurricane exposure measurement methods, and sample sizes. The studies employed a number of designs, including cohort, cross-sectional, and quasi-experimental. There was little uniformity in the methods employed for defining and measuring hurricane exposure. These inconsistencies limit the ability to make meaningful conclusions based on the body of evidence and render direct comparisons difficult. Therefore, future research should focus on understanding optimal methods of measuring hurricane exposure and optimal methods of estimating effects of hurricanes on maternal and child health outcomes.

Whereas most of the studies evaluated the population-level effects of hurricane exposure on maternal-neonatal health, researchers who used the Hurricane Experience Scale were able to measure individual-level exposure. However, no evidence of scale reliability and validity was presented in these studies.[37,39,40] There was also no consideration for how individuals perceived the relative severity of each discrete experience on the scale, precluding an understanding of the disproportionate effects of

hurricane related experiences. Despite the limitations of the Hurricane Experience Scale, individual experiences of hurricane related stressors are important to examine as the subsequent biobehavioral and metabolic changes associated with stress may contribute to adverse pregnancy and birth outcomes. Existing literature provides evidence of the relationship between stress and adverse perinatal health outcomes.[13,16,17] However, identifying stress effects can be challenging, especially in studies with smaller sample sizes. The lack of adequate power may preclude researchers from identifying relationships, demonstrated through statistical difference, that may be attributed to stress.

The findings addressed in this review also indicate that perinatal health effects of hurricanes may be dependent on the trimester of exposure.[32,33,35,44] While 4 studies evaluated trimester of exposure, they did not consistently identify which trimester(s) of exposure placed the woman at heightened risk. Therefore, it is important for future studies to continue evaluating potential role of trimester of exposure, as there remains little understanding into the mechanisms by which hurricanes might lead to adverse outcomes. Additional research should focus on providing clarity around how trimester of exposure affects risk for adverse health outcomes after hurricane exposure. If trimester of exposure is found to be a significant factor in determining risk for adverse pregnancy and birth outcomes after hurricanes, targeted hurricane preparedness plans and interventions could mitigate adverse outcomes for women that are at risk.

The areas of Louisiana that experienced the most significant damage from Hurricane Katrina reported declines in post-hurricane rates of low birth weight deliveries and preterm birth; however, there were reported increases in the rates of those

occurrences in surrounding areas, which received an influx of hurricane survivors.[28] This suggests that large scale displacement can be a significant confounding variable in studies examining hurricanes and birth outcomes. Accurately measuring effects of hurricanes after which significant population displacement occurred is difficult, limiting generalizability of study results. There are estimates that 10,000 pregnant women were displaced immediately before or after Hurricane Katrina[50] and data may be missing for this group. Failing to account for displaced populations may lead to under- or overestimation of hurricane-related effects on perinatal health. As changes in climate mean that superstorms causing catastrophic damage are likely to continue and worsen, ability to account for displacement and forced migration will be increasingly important when evaluating the effect of hurricane exposure on maternal-neonatal outcomes. Additionally, since the subsequent rise in poor birth outcomes in the states receiving Hurricane Katrina survivors was primarily limited to non-Hispanic Black women, it is important to consider how populations at known increased risk for poor birth outcomes may be further affected by displacement and stress associated with hurricanes and other natural disasters.

Despite some inconsistent findings, due in part to differences in methodology and general measurement challenges, it appears evident that hurricane effects are not experienced uniformly by all pregnant and postpartum women. Understanding who is most at risk and why remains a key unknown, but it is crucial information for use by clinicians, health systems, and local and federal governments, which can be used for the development of effective disaster preparedness and response efforts and public health infrastructure.

Implications

The results of this review show that hurricanes may negatively affect the health of pregnant women and their newborns. Nurses and midwives compose the largest segment of the global healthcare workforce,[51] and are often on the frontlines of disaster preparedness and response efforts. Therefore, nurses are well positioned to promote favorable outcomes for pregnant women experiencing hurricanes. It is essential that nurses in hurricane-affected areas understand the potential immediate and long-term effects of hurricanes on pregnancy and birth outcomes. Given the potential for large scale displacement, nurses and healthcare providers in areas receiving hurricane survivors should also be aware of the potential effects of hurricane-related stress on birth outcomes. Governments and healthcare systems should consider increasing the role of nurses in disaster preparedness and response plans directed at pregnant women and newborns.

Conclusion

Findings from this integrative review enhance current knowledge about the effect of hurricane exposure on adverse pregnancy and birth outcomes. The evidence reviewed suggests that hurricane exposure may be positively associated with adverse birth outcomes such as hypertensive disorders of pregnancy, gestational diabetes, labor complications, cesarean birth, and abnormal newborn conditions. There is also evidence that associations between hurricane exposure and preterm birth and low birth weight exist, some inconsistent findings may be related to the wide variety of methodologies of extant studies or to post-hurricane population changes. Future research should focus on identifying the most optimal methodologies for measuring

hurricane exposure and analyzing birth outcomes, addressing the role of displacement and migration, clarifying the effect of trimester of exposure, and evaluating individual-level effects. Nurses, key professionals within disaster relief programs, should be aware of potential perinatal health effects of hurricanes. As part of interdisciplinary teams, nurses can be leaders in developing and implementing hurricane preparedness and response policies and plans.

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Tables

Table 1. Summary of Included Studies in Integrative Review

Author Year	Location & Hurricane (Year)	Population Studied	Study Design	Outcomes	Birth Data Source	Results
Antipova & Curtis (2015)[36]	Louisiana Hurricane Andrew (1992)	All births from August 1992-August 1993 (one year after Hurricane Andrew in August 1992) (*N* = 38,004)	Retrospective	Low Birth Weight, Preterm Birth	Vital Statistics	No significant association between Hurricane Andrew and low birth weight births (OR = .97, 95% CI = [0.86,1.1]). Significant increase in preterm births after Hurricane Andrew (OR = 1.27, 95% CI= [1.12,1.44]; X^2 = 13.8, p < .001). The increase was also significant when stratified by race White (X^2 = 7.98) and Black (X^2 = 5.99), p = .01.
Chen et al. (2012)[27]	Alabama Louisiana Mississippi Hurricane Katrina (2005)	Births to African American and White Women living in Louisiana, Mississippi, and Alabama and across the United States before and after Hurricane Katrina (*N* = 1,467 counties/parishes; 81 in the Gulf Coast and 1,386 in the U.S.)	Retrospective	Low Birth Weight, Preterm Birth	Vital Statistics	The marginal mean difference (29.014, p < .001) in low birth weight pre- and post-Hurricane Katrina was significantly higher for African American women. White women did not experience a significant difference in low birth weight post-Hurricane Katrina. Both African American and White women experienced higher marginal mean difference rates in preterm birth when comparing the pre- and post-Hurricane Katrina periods. African American women had a higher marginal mean difference (40.083, p < .01) in preterm births than White women in the Gulf Coast (36.946, p < .01).
Currie & Rossin-Slater (2013)[33]	Texas Multiple Storms	All Texas births between 1996-2008 (*N* = 4,237,494).	Retrospective	Low Birth Weight, Gestational Age, Abnormal Newborn Conditions, Labor and Birth Complications	Vital Statistics	Authors did not find a significant association between hurricane exposure and low birth weight or gestational age. Hurricane exposure in second trimester (B = -0.0249, p < .05) is negatively associated with assisted ventilation of the newborn of any length of time. Hurricane exposure in first trimester (B = 0.0136, p < .05), second trimester (B = 0.0326, p < 0.0001) and third trimester

						(B = 0.0369, $p < 0.0001$) is significantly associated with meconium aspiration syndrome. Hurricane exposure in first trimester (B, 0.0150, $p < .05$) and third trimester (B = 0.0133, $p < .05$) was associated with newborn assisted ventilation over 30 minutes. Hurricane exposure in first trimester (B = 0.0165, $p < .05$) was associated with newborn arterial blood gas pH <7.2. Hurricane exposure in the third trimester was associated with an increase in labor and birth complications (B = 0.0409, $p < .001$). Hurricane exposure in the first trimester (B = .0144, $p < .05$) is associated with dysfunctional labor. Hurricane exposure in the second (B = 0.0239 = , $p < .05$) and third trimester (B = 0.0299, $p < .05$) is associated with moderate or heavy meconium staining of amniotic fluid. Hurricane exposure in the third trimester (B = 0.0161, $p < .05$) is associated with breech or malpresentation.
Grabich, Horney, et al. (2016)[30]	Florida 2004 Hurricane Season: Charley, Frances, Ivan, Jeanne	Florida women included with an estimated date of conception based on LMP between October 2003 and September 2004 (*N* not specified).	Retrospective	Preterm Birth and Low Birth Weight	Vital Statistics	Hurricane Ivan was positively associated with preterm birth (B = 0.03, p=0.4) when applying the model that utilized the continuous measure of maximum hurricane wind speed to determine exposure. However, the maximum hurricane wind speed exposure method yielded significant negative associations for the other Hurricanes Charley (B = -0.02, p = .01), Frances (B = -0.04, p=.01) and Jeanne (B = -0.03, p = .01). There were mostly statistically nonsignificant decreases in low birth weight with hurricane exposure. Hurricane Frances was negatively associated with low birth weight when applying the model of four-category Saffir-Simpson maximum wind-speed method (B = -0.98, p = 0.0007) and the binary >34mph wind-speed method (B = −1.68, p = 0.003). Adjusting for environmental and sociodemographic characteristics reverses the direction of the original calculated associations between hurricane exposure and low-birth

						weight. 32 of the 40 models adjusted to a more positive association.
Grabich, Robinson, et al. (2016)[29]	Florida Hurricane Charley (2004)	Births with an estimated date of conception between October 24, 2003 and September 26, 2004. Study population includes births conceived before Hurricane Charley (on August 13, 2004) and the last hurricane of 2004 (September 26, 2004) (*N* = 342,942)	Retrospective	Preterm and Extreme Preterm Birth	Vital Statistics	There were no significant association between hurricane exposure and preterm birth. Hurricane exposure (defined as >=39mph wind speed) (aHR =1.09, 95% CI= [1.03,1.16]) and hurricane exposure (defined as >=74mph wind speed) (aHR = 1.21, 95% CI= [1.06,1.38]) were positively associated with extreme preterm birth. White Hispanics were more likely than White non-Hispanics to experience extreme preterm birth with hurricane exposure (>=74 mph wind speed) (*HR*= 1.32, 95% CI= [1.04,1.69]).
Grabich et al. (2017)[31]	Florida 2004 Hurricane Season: Charley, Frances, Ivan, Jeanne	Florida pregnancies that completed a minimum of 20 weeks' gestation and that were conceived between January 2003 and October 200 (*N* = 382,700).	Retrospective	Low Birth Weight, Fetal Death Rate	Vital statistics records	There was no significant association between hurricane exposure (defined and analyzed in two ways: >39 mph winds and >79 mph winds) and low birth weight and fetal death rate.
Hamilton et al. (2009)[28]	Louisiana, Alabama, Mississippi Hurricane Katrina (2005)	Births from August 29, 2005-August 28, 2006. (*N* = 166,675).	Retrospective	Late or No Prenatal Care, Cesarean Birth, Preterm Birth, Low Birth Weight, Very Low Birth Weight	Vital Statistics	Among the 14 counties and parishes within 100 miles of the storm path, Alabama (2.2% to 2.7%)[a] and Mississippi (2.3% to 3.3%) experienced large increases in prenatal care. Non-Hispanic black women in Mississippi experienced an increase in late or no prenatal care (3.2% to 5.0%). Hispanic women experienced an increase in late or no prenatal care in Louisiana (2.3% to 3.9%).

						Among the total FEMA designated area in Louisiana, the percent of Hispanic women experiencing late or no prenatal care increased from 3.0 to 4.7. For the FEMA-designated area of 91 counties and parishes, there was a six percent increase in cesarean birth in Louisiana and a ten percent increase in cesarean birth rate in Alabama and Mississippi, when comparison the 12-month period after Hurricane Katrina to the 12-month period after Hurricane Katrina. Within the 14 counties and parishes, there was a decrease (3.2% to 2.4%) in very preterm births and very low birth weight births (2.3% to 1.8%). Blacks saw a 21% decrease in very preterm births in Louisiana. In Alabama, very preterm births rose from 3.1% to 3.8% in the hardest hit areas.
Harville et al. (2015)[37]	Louisiana Hurricane Katrina (2005)	Pregnant women were recruited between 2010 and 2012 (*N* = 308).	Prospective Cohort	Low Birth Weight, Preterm Birth, Birth Length, Head Circumference, Gestational Age, Birth Weight.	Medical Records	Experiencing hurricane-related injury was associated with preterm birth (aOR = 5.22, 95% CI= [1.60,17.06], $p < .01$). There was no significant relationship between hurricane exposure and low birth weight, birth length, head circumference, gestational age, and birth weight.
Harville, Tran, et al. (2010)[38]	Louisiana Hurricane Katrina (2005)	All births from 2003-2007 (*N* = 254,665)	Retrospective	Low Birth Weight; Preterm birth; Cesarean Birth	Vital Statistics	When comparing the 2 years post-Katrina to the 2 years pre-Katrina, there was a significant increase in low birth weight in Louisiana (aOR = 1.03, 95% CI= [1.00,1.06], $p = .04$) and cesarean births (aOR = 1.09, 95% CI, 1.08,1.11, $p < .01$). There was no significant change in preterm birth (aOR = 1.01, 95% CI=[0.98,1.03], $p = 1.65$). Non-Hispanic black (aOR = .82, 95% CI =[0.75,0.88], $p < .01$) and Hispanic residents (aOR = 0.72, 95% CI =[0.57,0.92], $p = .01$) in Region 1 (the area most strongly affected by the hurricane and flooding) experienced a significant reduction in preterm birth post-Katrina.

Mendez-Figueroa et al. (2019)[34]	Texas Hurricane Harvey (2017)	Women who participated in voluntary perinatal database with singleton pregnancy that gave birth at 24 weeks gestation or greater between August 2011-June 2018. (*N* = 29,179).	Retrospective	Preterm Birth, Cesarean Birth, Hypertensive Disorders of Pregnancy, Arterial Cord pH <7.1; Neonatal Morbidity, Suspected or Proven Newborn seizure, Neonatal Death		There was no significant association between Hurricane Harvey and preterm birth. There was a significant association between Hurricane Harvey exposure and: - Preterm birth (aOR = 1.14, 95% CI = [0.99,1.31], p < .05) - Cesarean birth (aOR = 1.18; 95% CI= [1.09,1.28], p < .05) - Hypertensive disorders of pregnancy (aOR = 1.52, 95% CI = [1.30,1.77], p < .05). - Arterial cord pH less than 7.1 (OR = 2.42, 95% CI = [1.67,3.52], p < .05) Women who reported that they were affected by Hurricane Harvey were more likely to experience composite neonatal morbidity, (aOR = 1.42; 95% CI = [1.03,1.94], p < .05), suspected or proven newborn seizure (OR = 17.1, 95% CI = [1.55,188.8], p < .05), and neonatal death (OR = 43.2, 95% CI = [5.03,370.6], p < .05).
Oni et al. (2015)[39]	Louisiana Hurricane Katrina (2005)	Women who were pregnant during Hurricane Katrina or became pregnant immediately after the storm (*N* = 220).	Cross-sectional and prospective cohort study	Induction of Labor, Cesarean Birth, Pregnancy Induced Hypertension, Gestational Diabetes	Medical Records	Exposure to stressful hurricane experiences was associated with induction of labor (aOR = 1.39, 95% CI = [1.03,1.86], p = .03). There was no significant relationship between hurricane exposure and cesarean birth, pregnancy induced hypertension or gestational diabetes.
Parayiwa & Behie (2018)[44]	Australia Cyclone Yasi (2011)	Births recorded in the Queensland Perinatal Data Collection from January 2008 to December 2012 (*N* = 311,389).	Retrospective	Preterm Birth Low Birth Weight	Vital statistics records	Women in their first trimester in cyclone Yasi-affected LGAs had a significantly higher proportion (9.6%, p = 0.008) and significantly higher odds (aOR = 1.26, 95% CI = [1.06,1.49], p < .05) of having a preterm birth, compared to women in unaffected LGAs. Authors did not find a significant variation in the proportions and odds of low birth weight in affected and unaffected LGAs.

Pomer et al. (2018)[45]	Vanuatu Cyclone Pam (2015)	70 women pregnant during Cyclone Pam	Cross-sectional	Birthweight	Birth records collected from hospitals and clinics	Experiencing post-Cyclone distress was significantly associated with decreased birthweight (ß -0.344, p = 0.011). Other measures of cyclone exposure, including timing of exposure (ß = 0.092, p = 0.435), objective hardship (ß -0.042, p = 0.744), dietary diversity ((ß -0.102, p = 0.420), and days without adequate food ($R^{2=}$ 0.025, p = 0.0194) and water (R^2=0.042, p =0.0091) did not predict birthweight.
Xiao et al. (2019)[43]	New York Hurricane Sandy (2012)	Study of immediate impact: 30 days after Hurricane Sandy (October 29, 2012 to November 27, 2012) as compared to the same time period in the pre- (2005-2011) and the post-Sandy years (2013-2014). Study of lasting impact: 12 months after Hurricane Sandy (November 2012-October 2013) as compared to the same time period between November 2005 and October 2014.	Retrospective quasi-experimental time series design	ED Visits for Pregnancy Complications, Threatened Abortion, Spontaneous Abortion, Threatened Labor, Early Onset of Birth, Renal Disease, Diabetes or Abnormal Glucose Tolerance, Gestational Hypertension, Renal Disease, Mental Illness, Cardiovascular Disease, and Infection of Genitourinary Tract.	Emergency Department Visits Data	During the month after Sandy as compared to the non-Sandy period ED visits for the following conditions experienced and excess increase. Pregnancy complications increased by 6.3% (95% CI = [2.2%,10.5%], p < .05), early onset of birth increased by 115.9% (95% CI = [6.9%,336.3%], p <.05), threatened abortion increased by 9.9% (95% CI = [4.0%,16.2%], p < .05), threatened labor increased by 10.1% (95% CI = [1.9%-18.9%], p < .05), renal disease increased by 73.2% (95% CI = [0.3%,199.4%], p < .05), and diabetes increased by 42.3% (95% CI = [15.0%,76.0%], p < .05). There was no significant change in spontaneous abortion, genitourinary tract infections, gestational hypertension, cardiovascular diseases and mental illness during the month after Sandy. ED visits for pregnancy complications were elevated significantly two months (2.4%, 95% CI = [0.4%,4.5%], p <.05) and three months (2.9%, 95% CI = [1.0%,4.8%], p <.05) after Sandy. ED visits for gestational hypertension, renal disease and mental illness after Sandy and peaked at seven months after Sandy increased by 21.9% (95% CI = [6.4%, 39.7%]), 7.3% (95% CI = [1.0%,13.9%]) and 33.2% (95% CI = [3.2%,72.1%], p <.05), respectively. The ED visits for diabetes mellitus or abnormal glucose tolerance increased by 26.3% immediately after Sandy and peaked at eight months after Sandy (95% CI = [3.9%,53.6%], p <.05).

Xiong et al. (2008)[40]	Louisiana Hurricane Katrina (2005)	Women recruited between January 2006 and June 2007 who were pregnant during Hurricane Katrina or became pregnant immediately after the hurricane (*N* = 301).	Prospective cohort study	Low Birth Weight, Preterm Birth	Medical Records	Having three or more severe hurricane experiences was significantly associated with an increased risk of having a low birth weight infant (aOR = 3.3, 95% CI= [1.13,9.89], $p < .01$). There was a nonsignificant increase in low birth weight (OR = 5.5, 95% CI = [1.19,25.4), *p* value not reported] and preterm birth (OR = 2.9, 95% CI = [0.49,17.1), *p* value not reported] for women who had four or more severe hurricane experiences.
Zahran, Breunig, et al. (2014)[42]	Louisiana Hurricanes Katrina and Rita (2005)	Vital statistics records including infant birth and fetal death data from January 1, 1999 and December 31, 2009 (*N* = 728,411)	Retrospective quasi experimental design	Fetal Death	Vital Statistics	Living in parishes with over 50% of destroyed housing was associated with fetal death (aOR = 2.367, 95% CI = [1.684,3.327], $p < .01$) when compared to mothers living with no major damage in their parish. There was an increase in risk of fetal death for mothers exposed to parishes with 10-50% damage (aOR = 1.396; 95% CI = [1.067,1.827], $p < .05$) when compared to mothers living in damages without serious damage. A one percent increase in housing stock destruction was found to increase the odds of fetal death by 1.7% (OR = 1.017, 95% CI = [1.011,1.024], $p < .01$).
Zahran, Magzamen, et al. (2014)[41]	Louisiana Hurricane Katrina and Rita (2005)	Births in New Orleans from January 1, 1999 to December 31, 2009 (*N* = 75,501)	Cross-sectional and Quasi-Experimental design	Eclampsia	Vital Statistics	Post Hurricane Katrina and Rita, there was a significant decline in soil Pb levels (t=2.74, $p < .01$). The risk of eclampsia declined significantly from 18.32 per 1000 births to 8.47 per 1000 births (t=5.38, $p < .01$). Pregnant women living in areas with large decreases in soil Pb (387.9 to 33.6 mg/kg) were less likely to suffer an eclamptic event (OR = 0.619, 95% CI = [0.397,0.963]). Pregnant women residing in areas with large amounts of soil Pb levels (95-333 mg/kg or >333 mg/kg) were 2.17 (95% CI = [1.49,3.14], $p < .01$) and 4.00 (95% CI = [3.00, 5.35], $p < .01$) times more likely to experience an eclamptic event.

Zahran et al. (2010)[35]	Florida and Mississippi Hurricane Andrew 1992	Births from 1991 to 1997 in hurricane-affected counties. (*N* not specified)	Retrospective and time series design	Fetal Distress	Vital Statistics	Infants experienced a statistically significantly higher risk of fetal distress during hurricane exposure period ($t = -3.903$, $p \leq .001$) as compared to non-exposure periods. Maternal exposure to Hurricane Andrew in the second trimester (OR = 1.20, 95% CI = [1.08,1.33], $p < .01$) and third trimester (OR = 1.26, 95% CI = [1.15,1.38], $p < .01$) increases the odds of fetal distress. African-American mothers exposed in the third trimester are 1.46 (95% CI = [1.26,1.70], $p < .01$) times more likely to give birth to an infant with fetal distress than white women. $10 million dollar increases in property damage raises the odds of fetal distress among pregnant women exposed to the hurricane (OR = 1.011, 95% CI = [1.01,1.02], $p < .01$). $1 billion dollar increase in property damage almost doubles the odds of fetal distress (95% CI = [1.91,4.31], p not provided).
Zahran et al. (2013)[32]	Florida Hurricane Andrew (1992)	All births in Miami-Dade and Broward Counties from 1992-1993 (*N* = 297,996)	Retrospective	Labor Dystocia; Cesarean Birth	Vital Statistics	Hurricane exposure in any trimester of pregnancy is associated with a statistically significant increase in cesarean birth (B = 0.026, $p < .05$). There is an approximately 20% increase in the risk for cesarean birth for pregnant women exposed to hurricanes. The risk is higher for women exposed in the second and third trimesters as compared to women exposed in the first trimester. Hurricane exposure in any trimester of pregnancy is associated with a statistically significant increase in labor dystocia (B = 0.10, $p < .05$). There is an approximately 50% increase in the risk of labor dystocia for pregnant women exposed to hurricanes. The risk is higher for women exposed in the third trimester as compared to women exposed in the first trimester.

Table 2. Summary of Hurricane Exposure Measures

Method	Description	Studies
Distance from Storm Path	Classifies area as exposed if they were directly on the storm track or within a specified distance of the storm track (0-100km).	*5 studies* Antipova & Curtis (2012)[36] Currie & Rossin-Slater (2013)[33] Grabich, Horney, et al. (2016)[a 30] Hamilton et al. (2009)[a,28] Zahran et al. (2010)[a,35]
Maximum Wind Speed	Categories developed from maximum wind speed of tropical storms and hurricanes. Wind speed of hurricanes correspond to the five categories of the Saffir-Simpson Hurricane Wind Scale.	*3 studies* Grabich, Horney, et al. (2016)[a,30] Grabich, Robinson, et al. (2016)[29] Grabich et al. (2017)[31]
Hurricane Experience Scale or Instrument	Questions designed to elicit responses regarding the severity of the participant's hurricane experience. Specific questions varied by study. Researchers in one study asked participants if they had been affected by the hurricane. Other studies asked whether the participant had experienced damage to their house, flooding in their house, felt their life was in danger, walked in floodwater, saw someone die, themselves or household member experienced illness/injury, someone important to them nearly died or experienced illness/injury. Some studies categorized these questions into three categories: danger, damage and injury.	*5 studies* Harville et al. (2015)[37] Mendez-Figueroa et al. (2019)[a, 34] Oni et al. (2015)[39] Pomer et al. (2018)[a, 45] Xiong et al. (2008)[40]
Housing Stock/Property Damage	Measures hurricane exposure and intensity through estimates of housing stock or property damage.	*2 studies* Zahran, Breunig, et al. (2014)[42] Zahran et al. (2010) [a, 35]
Geographical Location	Studies measured hurricane exposure based on participants' geographical location. Geographical location determined through self-report, vital statistics or other administrative data.	*7 studies* Chen et al. (2012)[27] Harville, Tran, et al. (2010)[38] Mendez-Figueroa et al. (2019)[a,34] Pomer et al. (2018) [a, 45] Zahran et al. (2013)[32] Zahran et al. (2010)[a, 35]

		Zahran, Magzamen, et al. (2014)[41]
Designated Disaster Area	Disaster designation through Federal Emergency Management Agency (FEMA) in the US or Australia's Commonwealth/State Natural Disaster Relief Recovery Arrangements (NDRRAs).	*4 studies* Grabich, Horney, et al.(2016)[a, 30] Hamilton et al. (2009)[a, 28] Parayiwa & Behie (2018)[44] Xiao et al. (2019)[43]

Note. This table provides a summary of hurricane exposure measures utilized in each study.
[a] Researchers in these studies utilized more than one measure of hurricane exposure.

CHAPTER 3: MANUSCRIPT TWO

The Experiences of Pregnant Women Exposed to Hurricanes Irma and Maria in the US Virgin Islands: A Qualitative Study

The Experiences of Pregnant Women Exposed to Hurricanes Irma and Maria in the US Virgin Islands: A Qualitative Study

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Abstract

Introduction

Hurricanes Irma and Maria hit the US Virgin Islands (USVI) in 2017. To date, there is no published literature available on the experiences of pregnant women in the Virgin Islands exposed to these hurricanes. Understanding how hurricanes affect pregnant women is key to developing and executing targeted disaster preparedness and response policies. The purpose of this study was to explore the experiences of pregnancy and birth among women in the USVI exposed to Hurricanes Irma and Maria.

Methods

We employed a qualitative descriptive methodology to guide sampling, data collection, and analysis. Semi-structured interviews of 30-60 minutes in length were conducted with a purposive sample of women (N = 18) in the USVI who were pregnant during or became pregnant within two months after the hurricanes. Interviews were transcribed verbatim and data were managed in MAXQDA. Team members developed a codebook, applied codes for content, and reconciled discrepancies. We thematically categorized text according to a conceptual framework of risk and resilience for maternal-neonatal health following hurricane exposure.

Results

Women identified components of risk associated with their hurricane exposure. Several themes emerged to describe risk at three ecological levels: individual ("We had to go without," and "I was supposed to be relaxing"); household/community ("I was really scared," and "Everyone was dealing with their own things"); and maternity system ("The hospital was condemned"). Descriptions of resilience also arose. Themes corresponding to resilience emerged at the following levels: individual ("Being calm"); household/community ("We shared our resources"); and maternity system ("On top of their game").

Discussion

Findings suggest that cyclical hurricane exposure in the USVI exposes pregnant women to risk. Clinicians, governments, and health systems should work collaboratively to provide targeted pre- and post-hurricane guidance and medical services to pregnant women. Women should receive support in developing pre-existing and new components of resilience to facilitate recovery.

Word Count: 300/300

Keywords:
Cyclone
Disaster
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Pregnancy outcome
Resilience
Risk

Introduction

Hurricanes Irma and Maria made landfall in the US Virgin Islands (USVI) on September 6, and September 20, 2017, respectively. Hurricane Irma caused widespread destruction, predominantly on St. Thomas and St. John, whereas Hurricane Maria devastated the island of St. Croix. As of March 2019, the joint estimated economic impact totaled approximately $1.54 billion along with acute stressors to public and private healthcare systems and processes, the economic and human toll of which as yet remains unknown.[1]

Combined, the hurricanes cut the daily inpatient capacity of the two major hospitals on the islands in half.[1] Both hospitals sustained immense infrastructural damage and combined attrition of approximately 138 medical staff members.[1] Some healthcare providers in private practice were unable to immediately resume clinical services, and others eventually left the island due to damage to their homes or their medical offices.[2,3] The impact of the hurricanes to routine and emergent inpatient and ambulatory care was significant; however, specific details regarding the hurricanes' impact on the maternity health system and the care of pregnant women have not been published.

Pregnant women exposed to hurricanes are at risk for adverse maternal and neonatal outcomes. As the most severe hurricanes are projected to grow in severity and frequency due to climate change,[4] understanding these risks becomes increasingly importantly. Studies of hurricanes in the United States and Australia have shown that exposure to a hurricane is associated with insufficient prenatal care,[5] preterm birth,[6,7] and increased rates of cesarean section delivery.[5,8,9] Hurricanes appear to negatively

impact the fetus and neonate by increasing the risk of fetal death,[10] meconium aspiration,[8] and neonatal morbidity.[9] There is also an association between prenatal hurricane exposure and postpartum symptoms of post-traumatic stress and depression.[11] The pathways through which hurricane exposure increases perinatal health risks are not completely understood. Severity of exposure and the associated stress accompanying traumatic events may explain why some pregnant women avoid harm while others are negatively impacted. For example, severe hurricane experiences—like walking through flood waters, being injured, or seeing a loved one die—are risks that are associated with increased preterm birth and low birth weight.[12]

While in-depth descriptions of women's experiences of pregnancy and birth during and after hurricanes can provide insight into how those individual experiences shape maternal and neonatal health outcomes, few published studies exploring these experiences exist. In two such studies, women who were pregnant during Hurricane Katrina in Louisiana or Typhoon Haiyan (Yolanda) in Japan described the stress associated with maintaining regular prenatal care, ensuring the wellbeing of their baby, and accessing diminished maternity services.[13,14] Participants reported struggling with depression and post-traumatic stress while striving to meet their own needs and those of their family members.[13,14] After Hurricane Katrina, women coped with the disruptions to their lives by creating new support networks.[13] Even 5 to 7 years after Hurricane Katrina, women were still experiencing significant disruptions in housing, employment, and psychosocial support, which negatively impacted their mental health.[15] Those extant studies provided important information about the impact of hurricanes on the experience of pregnancy after hurricanes; however, they did not provide in-depth

descriptions of risk and resilience. Additionally, to date, there are no published studies focusing on the experience of women in the USVI who were pregnant during and immediately after Hurricanes Irma and Maria.

To address this gap in knowledge, the purpose of this qualitative study is to describe the pregnancy and birth experiences of women in the USVI following Hurricanes Irma and Maria. Through in-depth interviews we identified factors that contributed to maternal and neonatal health risk and resilience. We also explored participant descriptions of hurricane-related deficiencies in prenatal or obstetric access, utilization, and quality.

Conceptual Framework

We employed an adapted socioecological conceptual framework to explore how experiences of risk and resilience can impact maternal-neonatal health following hurricane exposure (see Figure 2). Data from the interviews were organized within three levels adapted from Bronfenbrenner's ecological systems theory: individual, household/community, and society/system.[16] Sources of both risk and resilience for hurricane-affected pregnant women arise from each interrelated level.

We adapted our Conceptual Framework for Maternal-Neonatal Health Risk and Resilience following Hurricane Exposure from the UNICEF Conceptual Framework for Maternal and Neonatal Morbidity and Mortality which identifies contributors to maternal and neonatal morbidity and mortality.[17] These contributors to maternal and neonatal morbidity and mortality are presented as risks. We also included components of resilience at each socioecological level. Within this framework, resilience is understood

as the capacity “to adapt successfully to disturbances that threaten the viability, the function, or the development of that system.”[18] Both risk and resilience influence maternal and neonatal health outcomes.

Methods

Study Participants

We employed the Consolidated Criteria for Reporting Qualitative Research (COREQ) checklist in reporting the findings.[19] The purposive study sample included 18 women. Participants who met the following criteria were originally included in the study: 1) were 18 years of age or older; 2) were in the USVI during Hurricane Irma, Maria, or both; 3) were pregnant during the Hurricanes; and 4) gave birth in the USVI. We expanded the inclusion criteria after initial recruiting efforts, in order to increase the number of participants. The expanded inclusion criteria also included women who became pregnant within two months after the Hurricanes and those who gave birth off island.

The recruiting team consisted of the first author, a Certified Nurse Midwife and PhD candidate, and two trained local research assistants. Both research assistants held graduate degrees and were experienced in research study recruiting methods in the USVI. Recruitment strategies included word of mouth, Facebook posts in groups for residents of the USVI, snowball sampling, flyer distribution in public places, including daycares and medical offices, and events. We recruited participants with maximum possible variation with respect to age, parity, socioeconomic status, and perinatal

outcomes to gather a wide variety of experiences.[20] The first author conducted interviews by phone. None of the participants had any prior relationship with the interviewer. Recruitment ceased once saturation was achieved and it was determined that additional interviews would not elicit additional unique information pertinent to the research questions.[21,22]

Data Collection

Interviews were conducted between July 2019 and September 2019. The interviewer read the participants information about the purpose of the research study and informed them of the risks and benefits of participation. We informed participants that the research was part of the doctoral dissertation by the first author, who was a former resident of the USVI. Each participant provided oral consent and the interviewer compensated participants with $25 gift cards. Each interview lasted 30-60 minutes and the interviews were audio-recorded with participant consent. The semi-structured interviews were based on open-ended questions designed to explore participant experiences shortly before, during, and after the hurricanes (see **Appendix A**). The interviewer used probing questions to delve into the details of the hurricane preparation and recovery and understand the impact of the hurricane. Three pilot interviews were initially conducted and the first author made minor edits to the interview guide following those pilot interviews. Ethics approval for the interviews was provided by the Johns Hopkins University School of Medicine Institutional Review Board.

Reflexivity

Throughout the research process, the first author practiced reflexivity.[23] She was aware that her personal experience of growing up in the USVI, experiencing Hurricane Hugo, a destructive Category 5 hurricane that made landfall in the USVI in 1989, and subsequently conducting research as a current resident of the US mainland might impact the data collection and analyses processes. Specific actions included informal self-reflexive processes of how her identity as an insider-outsider might influence the development of an unbiased interview guide, decisions by participants about whether take part in the study, and the interpretation of the findings. She also engaged in reflexive practices with a senior team member in which she identified and confronted assumptions during the data collection and analysis process.

Data Analysis

Each interview was professionally transcribed and imported into MaxQDA2018 for data management. The first author checked each transcription for accuracy. The first author created an initial codebook with a priori codes prior to data collection, guided by a literature review and the conceptual framework.[24] Two authors (NJ and DW) independently read each transcript. Consistent with a qualitative descriptive methodology, we coded each transcript based on content, summarizing the events and experiences detailed by the participants.[25] We analyzed components of risk and resilience within the context of hurricane exposure. We reviewed the codebook after the interviews were completed and two authors (NJ and DW) made minor changes to the codebook during the coding process (see **Appendix B** for the final codebook). Coding discrepancies were negotiated and resolved through discussion.[24] Themes were

identified through a deductive process guided by the conceptual framework. We grouped participant experiences of pregnancy and birth during and after the Hurricanes into the three ecological levels identified in the conceptual framework, and further analyzed the interview transcripts for how they contributed to the women's experiences of risk and resilience during and shortly after the hurricanes.

Results

Participant Characteristics

Interview participants (see Table 3) were mostly African Caribbean/Black (*n* = 11). Three participants self-identified as multiracial, while the remainder (*n* = 4) were white. Three participants reported their ethnicity as Hispanic/Latina. The majority had a high school level of education or less (*n* = 10) and were employed full-time (*n* = 12). Annual household income varied; 6 participants reported incomes less than $25,000 per year, 7 reported incomes between $25,000 and $60,000, and 5 reported incomes over $60,000 per year. Ten of the 18 participants were married. The average age of participants was 31 years (overall age range between 18-42 years). At the time of the hurricanes, participants lived on St. Thomas (*n* = 9), St. Croix (*n* = 8), and St. John (*n* = 1). Fourteen women gave birth in the USVI, while 4 gave birth on the US mainland. All participants gave birth at a hospital. Over half (*n* = 10) of the participants had higher risk pregnancies with conditions including multiple gestation, hypertension, or gestational diabetes.

Table 3. Participant Sociodemographic, Pregnancy, and Birth Characteristics

Characteristic	n (%)

Age	
18-24	2 (11.1%)
25-29	6 (33.3)
30-34	7 (38.9%)
35-39	1 (5.6%)
40-44	2 (11.1%)
Race	
Black/African Caribbean	11 (61.1%)
White	4 (22.2%)
Multiracial	3 (16.7%)
Ethnicity	
Hispanic	3 (16.7%)
Not Hispanic	15 (83.3%)
Marital Status	
Never Married	9 (50.0%)
Married	8 (44.4%)
Divorced	1 (5.6%)
Employment	
Not Employed	5 (27.8%)
Part-Time	1 (5.6%)
Full-Time	12 (66.7%)
Education	
Less than High School	5 (27.8%)
High School	5 (27.8%)
Some College	3 (16.7%)
College	2 (11.1%)
Graduate	2 (11.1%)
Post-Graduate	1 (5.6%)
Household Annual Income	
$0-$15,000	3 (16.7%)
$15,000-$25,000	3 (16.7%)
$25,000-$60,000	7 (38.9%)
Greater than $60,000	5 (27.8%)
Island of Residence	
St. Croix (Hurricane Maria)	9 (50.0%)
St. Thomas (Hurricane Irma)	8 (44.4%)
St. John (Hurricane Irma)	1 (5.6%)
Gave Birth in the USVI	
Yes	14 (77.8%)
No	4 (22.2%)
Type of Birth	
Vaginal	9 (50%)
Cesarean	9 (50%)
Timing of Birth	
Full Term	18 (100%)
Pre-Term	0 (0%)

Hypertension	
Yes	5 (16.7%)
No	13 (83.3%)
Delay or Interruption in Prenatal Care	
Yes	12 (66.7)
No	6 (33.3)

Themes

We analyzed narratives of hurricane and hurricane recovery experiences within three socioecological levels: the individual, the household/community, and the maternity system. Within the individual level, the following themes described aspects of risk: poor nutrition and stress. The theme corresponding to individual resilience focused on personal coping strategies. Within the household/community level, the main themes describing risk centered on lack of support and the presence of physical/environmental hazards. At the household/community level, the resilience theme identified was abundant support. Within the maternity system level, the risk theme related to negative impacts on ambulatory and inpatient maternity care, and the theme related to resilience focused on the continuity of high-quality care provided by healthcare providers and hospitals.

Individual

Risk

Poor Nutrition ("We had to go without")

Participants described substantial changes to their access to fresh and nutritious foods after the hurricane. For many participants, pre-hurricane preparations included the anticipation of loss of electricity for an extended period, thus precluding the ability to

safely refrigerate fresh food. Some procured large supplies of canned foods and bottled water. Others reported more modest preparation efforts because they did not expect the hurricane to be severe. However, after the hurricanes, access to grocery stores was limited and non-perishable food items did not last long. Roads were blocked by fallen trees and other debris, and some stores had been heavily damaged and thus remained closed or offered very few supplies. Participants reported being limited to stores within walking distance. Access to prenatal vitamins was also disrupted when patients were unable to access pharmacies in a timely manner. Additionally, the curfew imposed immediately after the hurricanes restricted people to a 4-hour window during which to travel on the islands, exacerbating the difficulty with gathering necessary supplies.

Participants recalled relying on public distributions of Meals, Ready-to-Eat (MREs) as a main source of food. Dealing with long lines and rationing at grocery stores further frustrated participants. Given the significant changes in nutrition, participants reported being concerned that their baby was not receiving enough nutrients. One participant attributed her low gestational weight gain to the inadequate food availability:

> *And I lost a lot of weight… a lot. I wasn't gaining-- I gained - I kid you not - nine pounds through my whole entire pregnancy…The food was horrible, canned food. I wasn't eating healthy…The grocery store didn't have fresh food as much.*

Stress ("I was supposed to be relaxing")

Participants frequently cited stress as a major concern. Common stressors included contending with lack of electricity, unstable food and water, changing diets, alterations to employment, and fluctuations in income. One participant described how dealing with these difficulties, combined with being pregnant, exacerbated her mental health experience.

> *A hurricane is not an ideal situation and-- you know, for anybody to be in. But it becomes more complicated when you're pregnant. And the stress that it puts on you is a lot… a lot of people probably wouldn't be able to handle some of the stuff that I went through…with no lights and no running water…while you're pregnant.*

Participants frequently asserted that stress had negative effects on their pregnancy, and many expressed concerns with how the stress would impact their baby.

> *I tried my best not to stress, but I was so worried that there was going to be something wrong with her because I-- like, I'm supposed to be relaxing.*

Although friends and family offered shelter and other resources, displacement was a source of significant stress. Having just given birth, one participant described the emotional toll caused by enduring displacement while transitioning into her role as a new mother.

> *Even though it was a blessing getting everything that we needed from my in-laws, it was also really-- I won't lie. Just dramatic. And it was like, "Can't I be a mom by myself? Can I just be in my own privacy? Do I have to live with someone else?" Emotionally, it was…a lot for me in terms of just not being able to have my own privacy with my daughter as a new mom.*

Several women also described lingering symptoms consistent with depression and post-traumatic stress disorder (PTSD) after the hurricanes. Some participants reported that they avoided discussing their experiences with family and friends who lived on the mainland. Others described experiencing significant fear and anguish with impending thunderstorms or milder hurricanes after their experiences with Hurricanes Irma and Maria.

Resilience

Personal Coping Strategies ("Being Calm")

Participants reported using various coping mechanisms to deal with hurricane-related stress. For some, prayer and religious faith were essential components in their

ability to cope. Positive thinking, visualization, and gratitude were also employed. Many participants actively worked to maintain calm due to concern about the effect stress could have on their pregnancy.

> *I really did not want to have a home birth. That's why I was really so calm in my head and just trying not to have the pressure of the hurricane induce my pregnancy.*

Several participants coped by not focusing too intently on their situation. Some stated that, rather than delving into feelings of despair, they focused on survival and recovery, preparing for their birth, or on meeting the needs of other family members. One participant described how she was not able to fully process the complex emotions surrounding the trauma of the situation at the time of the recovery. Rather, the ability to process came later, after the acute recovery period had passed:

> *I didn't get to mourn or go through the process of "we're going through this aftermath." I feel like the entire time I was pregnant, I was just focused in on being calm the entire time. I didn't get to like take in [that] "this is devastating." It was not after maybe like months after was when I kind of like broke down and cried and realized we went through a category five hurricane and I was very pregnant and I had my 18-month old.*

Household and Community

Risk

Lack of Support ("Everyone was dealing with their own things")

Coping with the hurricane recovery period was especially difficult for those who found themselves with little support from friends and partners. Participants reported that receiving help from friends and family was sometimes difficult because everyone was managing their own needs:

> *Everyone was dealing with their own things and dealing with their houses and things like that. Typically…my mom would have come or my mother in law or my sisters in law, but everyone was dealing with their own things at that time. I mean*

> *they would still check up on me, but it wasn't like how it would have normally been.*

A minority of participants (*n* = 2), noted that lack of support from employers negatively impacted their ability to meet their needs. One participant noted that her employer made it difficult for her and her colleagues to prepare for the hurricane.

> *They didn't let us [leave work to get sandbags]. I [contacted HR]. I emailed everybody because I was so upset, but it just got ignored, conveniently…Their idea was, "Well, you're here to serve the public..." I'm like, "Well, that's perfect, but who's here to help out the people who serve the public?" Who's here to give us our little opportunity to prepare our homes? And that was an ongoing complaint between the administration and the [employees].*

Physical/Environmental Hazards ("I was really scared")

Participants described managing pregnancy in unsafe or dangerous circumstances during and after the hurricanes. During the hurricane, several women reported having to bend repetitively to mop flood waters that entered their homes. One participant recounted that she fell and slipped on pooled hurricane water. Maternity providers recommend that pregnant women be evaluated in the hospital after a fall, but this participant did not have the ability to safely seek medical attention during the hurricane. One woman who was experiencing regular uterine contractions on the night of the hurricane, which was her due date, recounts how she and her parents waded through flood waters to find help.

> *The water was waist deep to me…The water was just so high and dark, and I was scared. I was really scared. So, my parents cupped my hands between theirs… so nobody could trail away, because the current of the water was flowing pretty heavy as well. So, we walked through the water, and I remember stopping a few times because ... not knowing it was contractions ... And, my mom said, "We're almost there. We're almost there, baby."*

Several women reported having heard that the low pressure of hurricane systems sometimes caused women to go into labor. One participant described being nervous that her baby would come early:

> *Yeah, we were pregnant, and people have all manner of, "Oh, this is gonna happen, and this is gonna happen." And, and so, you know, a lot of people were like, "Oh, yeah premature babies." And I'm looking at people like, "No…We're not having a baby in the middle of a hurricane," you know? So, I'm like, rubbing my belly and talking to the baby. I'm like, "You better stay in there," you know?*

In the days after the hurricanes, driving or walking along the roads was dangerous because of fallen power lines, debris, and downed trees. One woman described climbing over downed trees while pregnant so that she could visit her family. Some participants were located in remote areas of the island without cell or landline phone service. They were concerned that, if they did have an emergency, they would be unable to call for help.

Resilience

Abundant Support ("We [shared] our resources")

Although some participants reported that they received minimal support from family and friends, most participants, however, described having abundant support from friends, family, coworkers, or church members. Neighbors checked on each other, sharing food and valuable information. Many participants had friends and family nearby who provided encouragement and tangible assistance:

> *My family and friends…they helped me a lot, especially my family [be]cause they came to check up on me to make sure that if we didn't have anything we would be able to get it. My friends helped me out as well because if somebody was cooking… they would give everybody a place to eat…And we would share our resources of food, [and] water…They was also making sure that, you know, I was safe, and I was okay.*

One woman described how she stopped caring for herself—for example, she stopped combing her hair—because of the stress, and how family came to her aid:

> *They were a very big support. I was so stressed-- I was [not] really combing my hair…. And my aunt was like, like, "Hey, we need to do something at least before you go into the hospital." So, she would braid it up for me. So, they were a very big support for me.*

Most participants who were employed noted that their employers were a source of significant help. Some participants continued to receive pay even though their place of work was temporarily closed due to damage. Others noted that their workplaces provided them with supplies, like generators, fans, food, and water.

> *And thank God I had such a great boss that, you know, she was very lenient. If I couldn't come in on certain days…she wouldn't expect me to come in. I can't complain…And not to mention as far as my employer, she was pretty helpful, like, "Okay, do you guys need water? Do you guys need this?" So that was a big help as well too.*

Some participants talked about the benefits of living in the USVI as opposed to other regions that had less hurricane exposure. Having endured destructive Category 4 and 5 hurricanes before, they felt like the recovery process improved with each hurricane.

> *If [we were in] in any other country or island, I don't think we would have been recovering so quickly. And we did have a really good recovery turnover after Maria…I've been through Hugo, and, you know, [this time] things wasn't that bad, you know?*

Maternity System Level

Risk

Negative impacts on ambulatory and inpatient maternity care ("I heard that the hospital was condemned")

Participants recalled concern regarding how the hurricanes' effects on hospital infrastructure and resources would impact their birth. Many women contemplated

leaving the USVI for their birth. Participants reported that they heard that much of the hospital had received major damage, that it was partially condemned, and that some of the services were being provided in mobile tents. One participant heard that they only had one functioning operating room. However, despite these rumored deficiencies, some were too close to their estimated due date to travel off island, either before or after the hurricanes, while others did not have the financial resources necessary to leave the island. Unless the participant had a high-risk pregnancy, most participants were provided reassurance by their healthcare provider of the state of the hospital's labor and birth services.

Most participants (*n* = 14) made an intentional decision to stay in the USVI for birth and found that the labor and birth floor had been largely spared and was functional. However, it still lacked many of the comforts and conveniences present prior to the hurricanes.

> *There was no hot water in the hospital... The hospital was technically condemned, and so that was a huge stressor for me, but the maternity ward and postnatal ward was supposed to be of good condition or whatever, but that was extremely stressful. I remember I really freaked out when I had heard that the hospital was condemned, but I didn't want to leave island because I didn't want to be away from my significant other for his first child. I didn't want that opportunity to be lost. They didn't tell you that they didn't have warm water either, so I went in for a shower. I ended up taking a cold, cold shower post C-section and oh my God.*

One participant noted that she overheard staff lamenting that they had been in the hospital for days after the Hurricane without being able to attend to their own families and homes. Another attributed her cesarean to the altered hospital capacity and infrastructure. Some participants experiencing high risk pregnancies (*n* = 4) noted that their healthcare providers recommended that they leave the island. Three of them

chose to leave the island and 1 remained. This participant, carrying twins, was originally planning to remain on island for her birth. However, after the hurricane hit, she recounts how her healthcare provider assisted her with leaving the island for her birth.

> *She kept trying to get us on a mercy flight…My pregnancy was already high-risk because I was carrying twins…They wanted to get the people with more serious problems out based off of how much was damaged, pregnant people and people with other problems… At the time they didn't have the necessary materials in case my babies were born [early]."*

Most participants reported having an interruption in their prenatal care ranging between 2 to 4 weeks. Many had a difficult time contacting their health care provider's office, complicating their attempts to resume prenatal care after the hurricanes. Some medical offices had been damaged and their physicians set up practice in temporary locations. Landline phones did not work, making attempts to contact health care providers still more difficult.

> *Um, it was a delay…I would say about for maybe like 2 to 4 weeks…But their building had got ruined, so they had to move somewhere else. And where they moved [the space was] a lot smaller. It took a little time for them to get over there. But I would say three weeks…*

This participant was offered a non-emergent, elective cesarean section when she went past her due date, but declined. With the impending hurricane, she made last-minute preparations for a potential unplanned, undesired, and unassisted homebirth should she go into labor during the hurricane.

> *They told [my partner] what to look for and he had ... two older kids [born through homebirth] already, so he knew just in case if I were to have a baby during the hurricane this is what to do. [My family was] prepared in regards to that, and luckily, we didn't need that… I mean I was thankful that we were prepared, but I really did not want to have a home birth.*

Resilience

Continuity of high-quality care provided by healthcare providers and the hospitals ("On top of their game")

In many ways, healthcare professionals and the hospital coordinated to ensure that women received proper maternity care. One participant who was past her due date during Hurricane Maria noted that a Certified Nurse Midwife on the island came to her house to ensure her wellbeing.

> *That day, my boss's husband, who was a federal agent at the time, and his friend went up to the north shore road to see if I was okay. Then, I was fine. Then after that, another [midwife], came by the house to see if I was okay. Everyone was worried because I was 42 weeks and I was still not having any contractions or anything like that.*

Some participants recounted that their obstetric care providers' offices were destroyed and that they had to receive care elsewhere. One participant noted that her provider started seeing patients in the hospital and that, because of a cloud-based electronic health records system, her provider was able to access her medical records.

> *The office was destroyed…she had to move to a temporary location where she was still seeing her patients at the hospital… So, my prenatal visits were just as frequent or regular, like, if I were-- not had the hurricane because she didn't make it any-- um, it's just that it was not in her office because it was destroyed... And most of her information was, you know, something online. So, she could have used her laptop to access our records. So that was a plus.*

Some participants went to their provider's office location in person to make an appointment to be seen. Others reported using social media, such as Facebook, or apps like WhatsApp to locate a cell phone number for their provider.

> *So about a week after the hurricane, we had no power or Internet, but in town, there was internet… A lot of the offices would post on Facebook temporary phone numbers. So, I think [the doctor's] office actually posted on Facebook a cell phone number.*

Despite prenatal concerns regarding the hospital, 14 of 18 participants gave birth on island. All but 1 of the participants who gave birth on island reported overall positive experiences with the care, the staff, and the facilities. Participants reported that was an adequate amount of staff and there was only minor damage to the labor and delivery floor. For example, one participant noted that, despite the lack of conveniences like hot water for baths, the quality of the care was good:

> *…The nurses and everyone there were amazing…My husband would tell me they didn't have running water, and they had to, like, boil water to bring it for his first bath. And, I [didn't] remember, until he told me, because they were just that good. They, they really were on top of their game.*

Discussion

The results of this qualitative study help illuminate the perspectives of women who were pregnant during and after Hurricanes Irma and Maria in the USVI. Participants described experiences that increased their pre- and postnatal risk factors, but also described components of resiliency that aided in their ability to withstand and overcome the disruption caused by the hurricanes.

Risk and Resilience at the Individual Level

Many women reported significant changes in their nutrition and access to prenatal vitamins after the hurricanes. Prior research has found that substantial reductions in food availability and in the quality of food consumption after a hurricane is associated with preventable birth defects. For example, Hurricane Gilbert hit Jamaica in 1988, after which the island experienced a significant rise in neural tube birth defects related to changes in access to foods high in folic acid.6/19/2020 1:13:00 PM Providing guidance to pregnant women in advance of a hurricane on appropriate food preparation and consumption during a disaster is therefore essential. To prevent neural tube defects, women could benefit from reminders of how to maintain adequate folic acid intake despite a changing diet. Additionally, given difficulties accessing food stores immediately after the hurricane and concerns around rationing, pregnant women should receive specific information regarding the amount of food they should store when preparing for a hurricane.

Participants also dealt with significant stress after the hurricanes. Stress is a well-established risk factor for adverse pregnancy outcomes.[27–29] Stress is a contributing factor for preterm birth,[6,7,12] as well as postpartum depressive and post-traumatic stress

symptoms,[11] following prenatal hurricane exposure. The narratives in this study primarily focused on stress in the immediate aftermath of the hurricanes; however, there is evidence that maternal hurricane exposure is associated with stress, depression, and post-traumatic stress symptoms extending as many as 5 to 7 years after hurricanes.[15] Therefore, relevant stakeholders should implement short- and long-term mental health support. Post-disaster mental health support should include counseling and therapy options to help women successfully navigate two simultaneous life stressors: childbearing and hurricane recovery.

Despite experiencing difficulty in securing adequate and nutritious food and in coping with stress, participants reported employing various self-directed coping strategies. Participants frequently cited positive thinking and staying calm as factors that contributed to their individual resilience. They also cited faith as an important component of coping and resilience. Similarly, Hurricane Katrina survivors depended on faith, religion, and spirituality to cope.[30,31] Helping women foster pre-existing and new coping strategies may help promote their recovery and contribute to resilience.

Risk and Resilience at the Household/Community Level

The findings of this study also suggest that pregnant women are often exposed to dangerous circumstances after hurricanes. Avoiding these circumstances is key because evidence suggests that these dangerous circumstances may put them additional risk of experiencing adverse pregnancy outcomes. For example, researchers in one prospective study conducted after Hurricane Katrina found that women who experienced injury during the hurricane were at increased risk for preterm birth.[32] Counseling women concerning how to identify a safe place to stay and avoid slips, falls,

and other dangerous circumstances within the specific context of household and environmental hurricane damage is an important point of hurricane preparedness guidance, which could potentially mitigate adverse pregnancy outcomes.

Some participants experienced a withdrawal of support at the household/community level, potentially further compounding the negative mental health effects of their hurricane experiences. Family and friends, preoccupied with employment or their own hurricane recovery efforts and responsibilities, were not always able to meet the participants' psychosocial and tangible needs in the same way as they might have before the hurricane. However, most participants noted examples of spontaneous community coordination in which family, friends, and neighbors shared resources cooperatively. These spontaneous behaviors are a form of social capital, which has been recognized as a component of community resilience.[33] Social capital, which incorporates bonding, bridging, and linking between social networks, has been linked to how communities successfully adapt and recover after natural disasters.[34,35] Future research might focus on how to cultivate and encourage the development and deepening of social capital after hurricanes to positively impact the experience of resilience for pregnant women.

Risk and Resilience at the Maternity System Level

The interviews revealed that women contended with delayed prenatal care, displaced maternity care providers, inaccessible medical records, and damaged hospital facilities. Some participants also noted the lack of guidance around preparing and dealing with a hurricane and its potential consequences while pregnant. After Hurricanes Irma and Maria, the 2 hospitals in the USVI were temporarily unable to

accommodate women with higher risk pregnancies, who would normally have been able to deliver on island. However, despite these challenges, women largely reported that they felt that the quality of their care was high. Narratives also revealed resilient practices like the use of social media in the post-disaster setting, cooperation between private providers and hospitals, home visits, and coordinated care planning for high risk pregnancies. The maternity system, although severely affected, exhibited an ability to absorb disruptions and respond to them effectively, in some cases altering their normal procedures to meet the extraordinary circumstances. These adaptive and transformative capacities are some of the hallmarks that define a resilient healthcare system.[36] Ultimately, the USVI health system should develop formal hurricane preparedness policies and plans that increase long-term resilience, especially given the threat posed by an annual hurricane season and forecasted increases in severe hurricanes.

Within the original conceptual framework, the maternity system is one component located within the larger societal/system level. However, there were few reflections by participants on underlying political, social, or economic structures. Hurricanes, like other "natural" disasters, are hazards shaped by government capacity, socioeconomic inequality, and other vulnerabilities. For example, in the case of Puerto Rico, another US territory, hurricane exposure are linked to colonialism, the decentralization of the hurricane preparedness and response efforts, and pre-existing socioeconomic disparities.[37] The USVI has a similar historical trajectory. However, while respondents were asked to comment on how living in a US territory may have impacted their

experiences, reflections on this historical trajectory did not emerge. Therefore, this study focused on the majority narratives which centered on the maternity system.

Limitations

This study had several limitations. First, the interviews were conducted 22-24 months after the hurricanes and recall bias can be a concern. However, studies show that women are capable of remembering specific details from their pregnancy and birth many years later.[38] Thus, recall bias was likely at least partially mitigated given the underlying context of the interviews. Second, our sample consisted predominantly of individuals who stayed on the island for birth. Although this was an intentional research design choice, we recognize that the results may not adequately reflect the experience of women who left the island to give birth and are not fully generalizable to all women who were pregnant and exposed to the Hurricanes. Therefore, future research should specifically address the experience of pregnant women who left the island after the hurricanes.

Implications

Policy

The interviews revealed that women generally felt that the USVI maternity system effectively met their needs. However, they did identify some gaps in their prenatal care as a result of the hurricanes. Women noted that they had difficulty procuring food, avoiding interruptions in prenatal care, managing stress, and receiving timely information regarding key services. Given the vulnerabilities specific to pregnant women, these findings suggest that greater collaborative efforts—on the part of maternity providers, hospitals, and the USVI Department of Health (DOH)—to develop

hurricane preparedness plans could mitigate some of these challenges. Coordinated efforts can include partnerships between the DOH and grocery stores, pharmacies, and the radio media. Policies might require retailers, such as grocery stores and pharmacies, to provide dedicated hours or expedited admission protocoles for pregnant women to access vital services.

Additionally, the DOH could work with the radio media to create a communication policy and plan for pregnant women, which could be broadcast at key intervals each day. Given concerns around prenatal and postpartum depression in the face of new stressors, these policies should also include a comprehensive plan to support perinatal mental health needs. To address the needs of high-risk pregnancies, it is imperative for relevant stakeholders to develop coordinated plans for any requisite medical evacuations. All coordinating entities should engage in periodic, year-round simulation planning to maintain readiness to successfully implement such plans. Finally, given the cyclical nature of hurricanes, individual maternity providers and nurses should be required to keep up to date on women's prenatal and postpartum concerns regarding emergency preparedness and planning as part of their licensure renewal process.

Clinical Practice

Individual maternity providers should develop hurricane preparedness policies and plans specific to their practice setting. Participants noted that, after the hurricanes, they had trouble accessing their medical records, contacting their maternity provider, and resuming prenatal care in a timely manner. Therefore, plans should ensure that providers can access patients' medical records, including contingency plans to access electronic medical records during a power outage. A comprehensive communication

plan should also be developed. Providers should consider making available a dedicated cell phone or text line to facilitate the communication of updated office hours, new office locations, and critical information regarding medical evacuation for high risk patients. Finally, in coordination with the DOH, post-hurricane home visits to high risk patients or to patients who are nearing or past their due date would provide an additional layer of support. All of these plans should be clearly communicated to patients prior to the start of hurricane season and reiterated as needed for the duration of hurricane season.

In addition to practice-specific plans and policies, maternity providers should provide patients with anticipatory guidance on safeguarding food, water, medicines, and supplies, finding a safe play to stay, emergency home birth, and staying safe in the aftermath of hurricanes. Providers should encourage each patient to develop their own personal and household plans in place to address these concerns. Providers should discuss pre-emptive plans for medical evacuation with anyone who is high risk. Maternity providers should also be attuned to mental health concerns of women and should keep an updated list of referrals for mental support. Each provider should also be comfortable with initiating or continuing medication therapy to address new onset or pre-existing perinatal mood disorders.

Research

The results of this study provide insight on the experience of women who were managing their pregnancy and birth after Hurricanes Irma and Maria. First-hand accounts provide valuable information to policymakers and clinicians regarding how to best provide quality maternity care after hurricanes. However, the sample did not include nurses, midwives, physicians, labor and birth staff, or representatives from the

DOH. Narratives from these professionals could also be particularly helpful in understanding the sequence of events prior to and after the Hurricanes; the rationale for hurricane preparedness and response policies; and the execution of these policies after Hurricanes Irma and Maria. Future research should include accounts from these key stakeholders, as they may be able to provide more context regarding how the maternity system responded to meet the needs of pregnant women on the islands and to identify areas for improvement and adaptation. Additionally, this manuscript focused on the experience of pregnancy and birth—with few narratives relating to the postpartum period. However, because participants provided many accounts of stress—and given the relationship between hurricanes and mental health concerns[11,15]—future research that includes the perspective of postpartum women should also be undertaken.

Conclusion

This study investigated the experience of managing pregnancy and childbirth during and after Hurricanes Irma and Maria in the USVI, including in-depth descriptions of risk and resilience at the individual, household/community, and maternity system levels. To improve care for pregnant women experiencing hurricanes and other natural disasters, it is imperative to provide adequate pre-hurricane preparation guidance. Public and private health organizations should widely broadcast information about resuming prenatal care, leaving the island for medical emergencies, and ensuring sustained access to food and clean water. Despite concerns around hospital damage, inadequate staffing, and deficient care, participants' lived experiences indicate that the maternity system in the USVI was resilient. Hospitals, clinics, and private providers

worked together to monitor pregnant women in late gestation, to meet the immediate medical needs of those with high risk pregnancies, and to resume normal operations as quickly as possible. This study indicates that there are specific strategies that could improve hurricane preparedness and planning to help individual women, their community and household, and the maternity system thrive in the face of cyclical hurricanes.

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CHAPTER 4: MANUSCRIPT THREE

Maternal-Neonatal Health following Hurricanes Irma and Maria in the US Virgin Islands: A Mixed Methods Study

Maternal-Neonatal Health following Hurricanes Irma and Maria in the US Virgin Islands: A Mixed Methods Study

Target Journal: Disaster Medicine and Public Health Preparedness

Abstract

Objectives: The purpose of this study was to investigate maternal and neonatal health outcomes in the US Virgin Islands (USVI) following Hurricanes Irma and Maria.

Methods: A convergent mixed-methods approach was used. The quantitative phase utilized an interrupted time series analysis of USVI birth data to examine if the hurricanes impacted the level and trend of no prenatal care (NPC), hypertensive disorders of pregnancy (HDP), preterm birth (PTB), cesarean birth (CB), small for gestational age (SGA) and low birth weight (LBW). Women's (*N* = 18) experiences of pregnancy and birth during and after hurricane exposure were explored through in-depth interviews.

Results: In the post-hurricanes period, the USVI experienced a significant decrease in the trend of SGA (B=-0.347; *p*=.037) and an increase in the trend of PTB (B= 0.364; *p*=.004). Women with high-risk pregnancies reported that their maternity providers recommended relocation to the United States. High stress characterized women's experiences.

Conclusions: Maternity providers and health systems should be aware of the potential impact of hurricane exposure on PTB rates. Facilitating the transfer of women with high-risk pregnancies may influence post-hurricane trends of SGA. Resilience after maternal exposure to hurricanes may be a protective factor against some adverse maternal-neonatal outcomes.

Word count: 198/200

Target Journal: Disaster Medicine and Public Health Preparedness

Introduction

In September 2017, the US Virgin Islands (USVI) were struck by two Category 5 hurricanes: Hurricanes Irma and Maria. The hurricanes caused catastrophic damage and significant disruption to the healthcare system.[1] Thus far, published analyses of the medical impact of the hurricanes have focused on medical encounters in the emergency department and in shelter-based health clinics. The emergency department saw a significant increase in patients with complaints related to chronic illnesses, such as diabetes.[2] Many residents also sought medical care at shelters for general health maintenance, exacerbation of chronic health conditions, mental health conditions, and injury.[3] There is little available data on the impact of the hurricanes on maternal-neonatal health utilization and access. Emergency department visits for pregnancy, childbirth, and postpartum care fell from 25.5 visits to 19.7 visits per 1000 visits.[2] Further, only 0.4% of all shelter visits were for primary pregnancy or postpartum complaints.[3] Analyses of the impact of the hurricanes on maternal-neonatal outcomes have not yet been published.

Accumulating epidemiologic evidence suggests that maternal exposure to hurricanes negatively impacts pregnancy and birth outcomes. While methodological heterogeneity contributes to some inconsistent results (N. Jeffers and N. Glass, unpublished data, 2020), hurricane exposure during pregnancy has been associated with preterm birth,[4–6] cesarean birth,[7] low birth weight,[8–10] neonatal morbidity[11] and fetal death.[12] There has been considerably less attention to outcomes such as prenatal care, hypertensive disorders of pregnancy, and small for gestational age, even though those outcome contribute to maternal and neonatal morbidity and mortality.[13,14] Additionally,

while the Caribbean faces cyclical hurricane exposure, the majority of population-based studies that focus on the perinatal epidemiology of hurricane exposure have been conducted in the Southeastern United States. One retrospective case control study in Jamaica noted the rise of neural tube defects after Hurricane Gilbert altered access to common foods that are traditionally good sources of folic acid.[15] Extant literature examining perinatal health effects of hurricanes in the Caribbean is sparse.

Quantitative studies provide important information about the impact of hurricanes on pregnancy and birth outcomes but it can be difficult to contextualize their findings in isolation. A small number of qualitative studies have addressed the experiences of pregnant women with Hurricane Katrina in Louisiana[16,17] and Typhoon Hainan (Yolanda) in Japan.[18] These studies found that pregnant women experienced significant disruptions in normal life, changes in social support, and diminished maternity services.[16–18] Employing mixed methods could help researchers further support study conclusions.

Hurricanes Irma and Maria provide an opportunity to conduct a natural experiment to understand the impact of these storms on the maternal-neonatal health of the USVI. The purpose of this study is to understand the impact of Hurricanes Irma and Maria on maternal-neonatal health outcomes in the USVI on a population and individual level. To answer this research question, it is important to triangulate information from multiple sources. Two phases of data collection and analysis were necessary to fully understand the impact of these hurricanes on maternal-neonatal outcomes. Therefore, this study involved a mixed methods approach to optimize the advantages of both the collection and analysis phases of research.[19]

During the quantitative phase of this study, we examined the longitudinal relationship between exposure to Hurricanes Irma and Maria in the USVI and maternal-neonatal outcomes, including no prenatal care (NPC), hypertensive disorders of pregnancy (HDP), cesarean birth (CB), preterm birth (PTB), low birth weight (LBW) and small for gestational age (SGA). We employed a quasi-experimental interrupted time series (ITS) design to understand the impact of Hurricanes Irma and Maria on maternal-neonatal outcomes in the USVI.[20] In the qualitative phase we explored experiences of pregnancy and birth among women who were pregnant during Hurricanes Irma and Maria in the USVI or who became pregnant within two months after the hurricanes.

Methods

Mixed Methods Design

The study is a convergent mixed methods design, in which the qualitative and quantitative phases were conducted simultaneously. Figure 1 shows the sequence of the research process.[19]

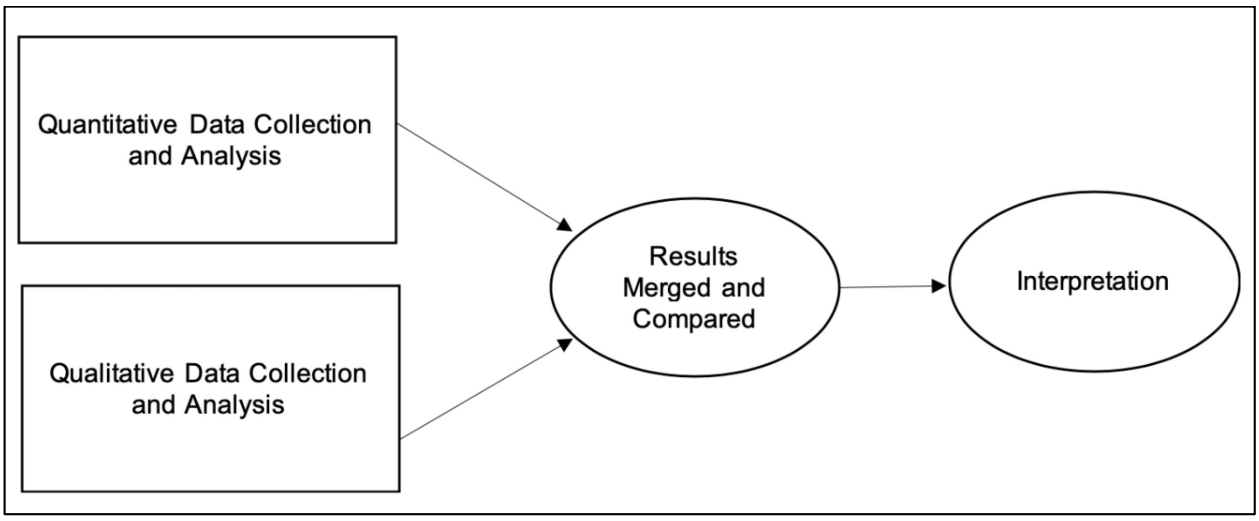


Figure 4. Convergent Mixed Methods Design[19]

In this convergent design, we collected and analyzed the quantitative and qualitative data independently. The quantitative phase was designed to estimate the longitudinal causal effect of hurricane exposure on maternal-neonatal outcomes in the USVI. During the qualitative phase, in-depth interviews explored the experiences of pregnancy and birth of women who were exposed to Hurricanes Irma and Maria. Pregnant women or women who became within two months after the storms were eligible to participate. We merged the data of each phase and interpreted them jointly.

The integration of qualitative and quantitative data allows researchers to better address the research question by taking advantage of the strengths of each individual phase.[19] Integration may occur at the levels of study design, methods, interpretation, and reporting.[21] For this study, we incorporated integration of the quantitative and qualitative phases at the study design level. We also integrated the data from the two phases during the interpretation and reporting phase. We merged the results and used the qualitative findings to provide context and possible explanations for the results of the quantitative findings.

Quantitative Methods

We employed a quasi-experimental, ITS design to estimate the longitudinal causal effects of 2017 Hurricanes Irma and Maria on adverse pregnancy and birth outcomes in the US Virgin Islands. A segmented regression analysis of time series data was employed to estimate the change in the monthly rates of NPC, HDP, CB, PTB, LBW, and SGA in the USVI in the 32 months before and 21 months after Hurricanes Irma and Maria. We hypothesized that the USVI would experience an increase in both the level and trend of each outcome in the post-hurricanes period.

Interrupted time series analysis enables researchers to examine time series data to determine if an event, or an interruption, led to a change in the outcome (see Figure 5.). While ITS can be used in randomized clinical trials, it is a particularly robust option when randomization is not feasible in the case of natural experiments that occur in real-world circumstances, such as hurricanes.[22] A time series is a series of repeated observations on 1 or more variables within a population taken at regular intervals over time. The design first establishes the baseline, or pre-event, trend. It then estimates the counterfactual or expected trend: the anticipated trend in the outcome had the intervention or event not occurred. The subsequent analysis determines if the observed post-event trend is significantly different from the pre-event trend. If so, then there is statistical evidence to suggest an association between the event and the outcome.

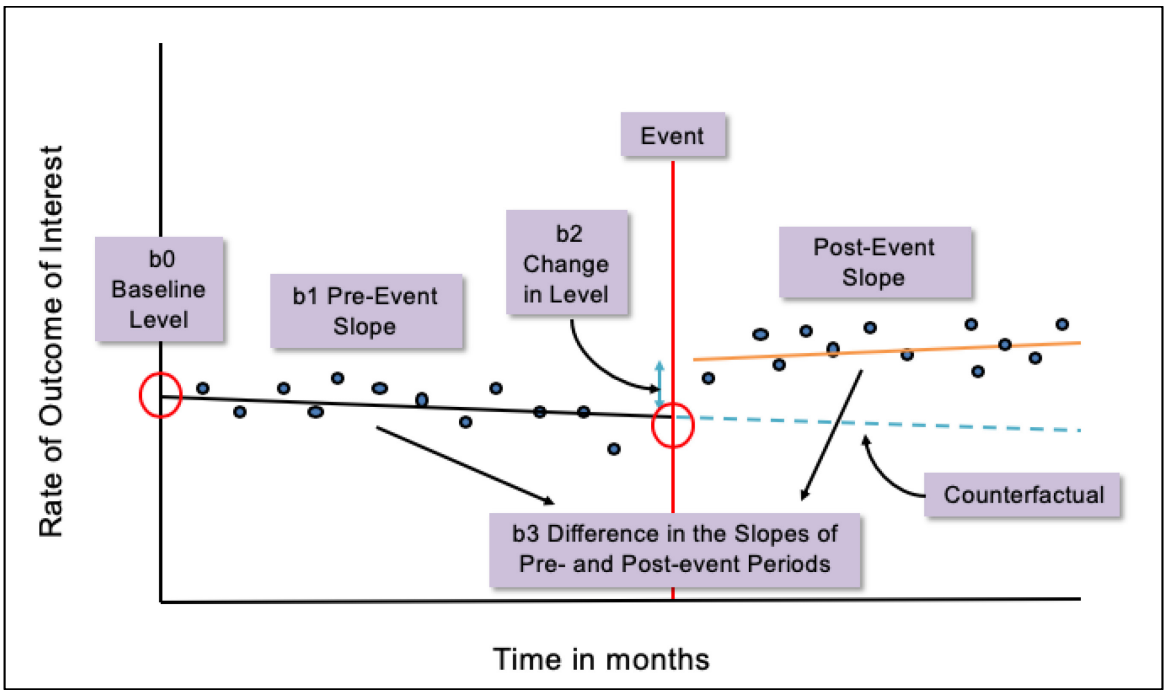


Figure 5. Interrupted Time Series Analysis

A Comparison Model

The internal validity of the study can be improved through the use of a comparison population that was not exposed to the event. If a significant effect is found only in the exposed population and not in the comparison population, that increases confidence that the identified effect is due to the event of interest. If a significant effect is observed among both populations, then that result suggests that another event or intervention may have affected both populations and is the cause of the effect.[23,24] Therefore, to control for changes in possible confounders over time, we conducted a stratified ITS analysis of maternal and neonatal outcomes utilizing the continental United States as a comparison group. We noted that several major hurricanes impacted the United States in 2017, including Hurricanes Harvey, Maria, and Florence. Births in the affected states of Texas, Florida, and North Carolina were removed to account for

the potential effects of these hurricanes. Therefore, we expected that the results of the ITS of the US birth data would not yield significant findings in the changes in level or trend of the study outcomes at the time of the hurricanes in the USVI.

Data Source

We used de-identified, aggregate birth data from the USVI Department of Health, which includes counts for key pregnancy and birth outcomes in the territory each month.[25–29] For the US comparison analyses, we used the restricted natality files from the Vital Statistics System of the National Center for Health Statistics.[30–33] These datasets include individual-level birth statistics for each state.

Data Collection

For the USVI, the time period of analysis ranged from January 2015 to June 2019, with the exception of data regarding low birth weight births, for which we only had access to information through December 2018. The time segments in this study included 32 months in the baseline pre-hurricane period (January 2015 to August 2017) and 21 months in the post-hurricanes period (October 2017 to June 2019). We removed data September 2017 for all analyses. A total of 53 months are included in the analysis for HDP, PTB, CB, and SGA. For LBW, 47 months are included in the analysis: 32 months in the pre-Hurricanes period (January 2015 to August 2017) and 15 months in the post-hurricanes period (October 2017 to December 2018). For the US data, birth data was only available through December 2018. The time period of surveillance in the US ranged from January 2015 to December 2018. The time segments for the US data include 32 months in the baseline period (January 2015 to August 2017) and 15 months in the post-hurricanes period (October 2017 to December 2018).

Power

Zhang et al.[34] developed a simulation-based method to estimate the power of segmented autoregressive models with effect sizes 0.5, 1, and 2 and autocorrelation ranging from -0.9 to 0.9. To estimate the power in this study, we assumed an autocorrelation of 0.3, which is derived from 48 months of US preterm birth data from 2014 to 2017 census information. If we assume a moderate effect size of 0.5, the study has a power of greater than 0.9 to detect a significant change in both the level and trend of the maternal and neonatal outcomes after the hurricanes.[34]

Measures

Defining Covariates and Outcomes

The primary outcomes of interest in this study included rates of NPC, HDP, PTB, CB, SGA, and LBW. No prenatal care is defined as a person who did not initiate prenatal care at any point in the pregnancy. HDP are a group of hypertensive disorders including gestational hypertension, preeclampsia, and eclampsia, which may occur during pregnancy or in the postpartum period. A PTB is a birth that occurs at less than 37 weeks and 0 days gestation. In a CB, the route of delivery is through an abdominal and uterine surgical incision. An infant born in the SGA category weighs less than 10% of the expected weight for its gestational age. The LBW designation describes newborns who weigh less than 2500 grams at birth.

We also considered the potential inclusion of race, ethnicity, advanced maternal age (AMA), and teen pregnancy as covariates in the final model. Race included individuals who were identified as not Hispanic and African American, white, and Asian. Ethnicity included individuals of Hispanic origin. The AMA categorization indicated that

the woman who gave birth was 35 years of age or older. Teen pregnancy included all births to women 19 years old or younger.

Using the available data, we determined the monthly rate for each covariate and each outcome variable per 100 births. Separately for each variable, we calculated the numerator as the number of births that met the above specified criteria. The denominator was the number of total births observed that month. The rates were multiplied by 100 to yield the rate per 100 births.

Statistical Analysis

Outcomes

We evaluated the pre- and post-hurricanes data for linearity, seasonality, and autocorrelation. Birth data, including PTB,[35] birth weight,[36] and HDP,[37] often exhibit significant seasonality. We examined scatterplots of each outcome and each covariate against time visually for autocorrelation and significant seasonality. We also analyzed the autocorrelation function plots of each variable. For each outcome and covariate, and separately for each site, we determined whether each outcome needed to be adjusted for autocorrelation with an autoregressive term at the appropriate lag. For data that exhibited no autocorrelation, we utilized a linear regression model.

Covariates

We conducted a time series analysis to determine if each potential covariate was changing significantly over time in each study setting. We used the following equation:

$$Y_t = b_0 + b_1 time$$

The coefficient b_0 estimates the baseline level of the outcomes at the beginning of the observation period; b_1 estimates the trend, or the rate of change in the proportion of

births with a specified outcome over time. The covariates that were changing significantly over time were included in the main segmented regression analysis. We applied each regression analysis separately to the USVI data and the US data.

Segmented Regression Analysis

For the main analysis, we utilized an autoregressive integrated moving average (ARIMA) model for data that exhibited high autocorrelation and seasonality and linear regression for those that did not. We used the following segmented regression equation:

$$Y_t = b_0 + b_1 time + b_2\, event + b_3 time\_after\_event$$

We used the coefficient b_0 to estimate the baseline level of the outcomes at the beginning of the observation period; b_1 to estimate the slope of the baseline trend, or the rate of change in the proportion of births with a specified outcome that occurred before the hurricane; b_2 to estimate the change in level of outcomes from the month immediately prior to the hurricane as compared to the month immediately after the hurricane; b_3 to estimate the change in the slopes of outcomes from the before the hurricanes to after the hurricanes. The variables related to time include the continuous *time* variable, which counts the number of months since the starting period of the study; an indicator variable *event* for whether a month was before or after Hurricanes Irma and Maria (0 for any month before September 2017 and 1 for any month after September 2017); and the *time_after_event* variable, which counts the number of months since the Hurricanes. We used the coefficients b_2 and b_3 to test the study hypotheses; the hypothesis is supported if either b_2 or b_3 are significant. We conducted all analyses in Stata 15 and utilized a two-sided test with significance level set at 0.05.

Qualitative Methods

Data Collection

We conducted semi-structured, in-depth interviews (N = 18) by telephone from July 2019 to September 2019. The full details of the qualitative methods have been previously described in another manuscript (N. Jeffers et al., unpublished data, 2020) The interviews were designed to explore the experience of managing pregnancy and birth during and after a major hurricane (see **Appendix A** for the full interview guide). Trained local research assistants conducted purposive sampling and participant recruitment via word of mouth, flyers, posts on Facebook groups pertaining to the USVI, and snowballing. Participants were informed of the purpose of the study and that their participation was voluntary. Each participant provided oral consent for the interviews.

The interviews were conducted by the primary author (N.J.) and lasted approximately 30 to 60 minutes. Prior to the interviews, the participants were asked to complete a brief sociodemographic, pregnancy, and birth questionnaire. All interviews were audio recorded, transcribed verbatim, and deidentified.

Analysis

We entered interview transcripts into the qualitative analysis program, MAXQDA, and analyzed the data using qualitative descriptive methods.[38] We developed an a priori codebook based on a literature review and the interview guide.[39,40] The codebook was further refined after three pilot tested interviews. Two authors (N.J. and D.W.) applied codes to the text independently (see **Appendix B** for the final codebook). After initial analysis of both the quantitative and qualitative results, the authors worked to understand the results of the ITS in light of context provided by the in-depth interviews.

For the purposes of integrating the qualitative and quantitative data, we focused on emergent themes we identified as having potential to explain the quantitative findings. Three themes emerged from the qualitative data that can provide context to the quantitative data: migration, stress, and resilience.

Ethics

We obtained ethics approval for both the qualitative and quantitative phases of this study from the Johns Hopkins Medicine Institute (JHMI) Institutional Review Board (IRB). The USVI Department of Health provided a letter of support for submission to the JHMI IRB.

Results

Quantitative Results

We calculated frequency and rate of maternal characteristics and birth outcomes by comparing the pre- and post-hurricanes periods (see Table 1). The total number of births in the USVI ranged from 63 to 145 births each month. In the pre-hurricanes period, the average monthly number of births was 98.3, as compared to 80.1 births in the post-hurricanes period. For the United States, our comparison group, the average monthly number of births in the pre-hurricanes period was 265,698.6 and 256,336.8 births in the post-hurricanes period. In the USVI, most infants were born to Black/African Caribbean women (71.73% pre-hurricanes and 69.03% post-hurricanes) while in the US most infants were born to white women (54.59% pre-hurricanes and 54.21% post-hurricanes). The percentage of births to AMA women increased for both the USVI (from

16.22% in the pre-hurricane period to 17.00% in the post-hurricane period) and the US (from 17.17% in the pre-hurricanes period to 18.60% in the post-hurricanes period). Teen births decreased for both locations as well. Each outcome of interest increased slightly in the post-hurricane period for both the USVI and US with the exception of small for gestational age in the US which was relatively stagnant.

Table 4. Demographic and Obstetric Outcomes Before and After Hurricanes Irma and Maria by Location (USVI and US)

	USVI		US	
	Pre-Hurricanes	**Post-Hurricanes**	**Pre-Hurricanes**	**Post-Hurricanes**
Mean Births	98.3	80.1	265698.6	256336.8
Race/ethnicity				
Non-Hispanic White	6.03%	3.83%	54.59%	54.21%
Non-Hispanic Black	71.73%	69.03%	13.51%	13.9%
Asian	0.80%	1.10%	6.74%	6.87%
Hispanic/Latinx	14.11%	15.19%	19.96%	20.32%
Maternal Age				
Advanced Maternal Age	16.22%	17.00%	17.17%	18.60%
Teen	7.28%	6.07%	5.21%	4.59%
Outcome				
No Prenatal Care	8.84%	12.86%	1.30%	1.45%
Hypertensive Disorders of Pregnancy	1.66%	2.63%	7.87%	9.36%
Cesarean Section	29.91%	32.16%	31.07%	31.26%
Preterm Birth	8.01%	10.92%	9.68%	9.89%
Low Birth Weight	4.71%	5.75%	8.04%	8.20%
Small for Gestational Age	4.32%	4.90%	7.83%	7.83%

We evaluated maternal characteristics using a time series analysis for potential inclusion of several additional factors as covariates. The results of the analysis showed that, in the USVI, only the rate of teen births changed significantly over time (B = -0.05; *95% CI* [-0.105, -0.003]; *p* = 0.036). In the United States, births to women of AMA (B = 0.001; *95% CI* [0.0005, 0.0006]; *p* = <0.001.), teens (B = -0.003; *95% CI* [-0.0003,-0.0002]; *p* =<0.001), NH black (B =0.02; *95% CI* [0.008, 0.031]; *p* = 0.001), and Hispanic women (B = 0.0002; *95% CI* [0.000-0.0004]; *p* = 0.002) changed significantly over time. These covariates were included in the final models.

Autocorrelation analysis of the outcomes revealed significant autocorrelation in the US data. For the USVI, the appropriate autoregressive lag identified was 1 for preterm birth, 2 for no prenatal care, and 2 for small for gestational age. Hypertensive disorders, LBW, and CB did not exhibit a lag. In the US data, the appropriate autoregressive lag identified was 4 for HDP, 3 for CB, 2 for NPC and 1 for PTB, LBW, and SGA.

Interrupted Time Series Analysis

USVI Model

We performed interrupted time series regression analysis for each variable to compare time trends before and after the hurricanes in the USVI. Results of the final models for each analysis are included in Tables 5-10 and Figures 6-11, as well as in **Appendix C**. We first investigated whether Hurricanes Irma and Maria caused an abrupt change in adverse maternal-neonatal outcomes. In the regression model, parameter b_2 represents the abrupt change in level between the pre- and post-

hurricanes periods. None of the outcomes exhibited significant changes in level between the pre- and post-hurricanes periods.

We then investigated whether there was a change in the monthly trend of adverse maternal-neonatal outcomes when comparing the pre-hurricanes period and the post-hurricanes period. We found that SGA and PTB exhibited significant changes in the monthly trend in the post-hurricanes period. The remaining outcomes: NPC, HDP, CB, and LBW did not exhibit significant changes in the monthly trend in the post-hurricanes period.

In the regression model, parameter b_3 represents the change in trend (slope) between the pre- and post-hurricanes periods. SGA births decreased in trend in the post-hurricanes period (B = -0.347; *95% CI* [-0.67, -0.02]; p = .037). We found that, at baseline, 2.33 out of every 100 births were of newborns of SGA. From that baseline level, there was an increasing pre-hurricanes trend of 0.12 SGA births per month. Immediately following the hurricanes, this figure increased by another 1.171 SGA births per month. Over time, this started to decrease significantly by 0.35 SGA births per 100 births per month.

The trend of preterm birth increased significantly in the post-hurricanes period (B = 0.36; *95% CI* [-1.45, 0.19]; p = .004). At baseline in the pre-hurricanes period, 7.46 out of every 100 births were preterm. The baseline trend was flat over time. Immediately following the hurricanes, it decreased by 1.11 preterm births per month, then the trend increased significantly in the post-hurricanes period by 0.36 preterm births per 100 births per month.

Comparison (U.S.) Model

In the US comparison model, PTB (B = 0.033; *95% CI*, [-0.57, -0.08]; *p* = 0.009). and LBW (B = -0.18; *95% CI*, [-0.32, -0.04]; *p* = 0.010) exhibited significant abrupt changes in level immediately after Hurricanes Irma and Maria in September 2017. For PTB at baseline, in the pre-hurricanes period, 8.16 out of every 100 births were preterm. The baseline trend decreased very slightly by 0.03 out of every 100 births per month. Immediately following the hurricanes, it exhibited a significant abrupt decrease by 0.033 births per month and then increased in the post-hurricanes period towards a trend of 0.02 per 100 births per month. For low birth weight, at baseline in the pre-hurricanes period, 1.47 out of every 100 births were preterm. The baseline trend decreased by 0.03 out of every 100 births per month. Immediately following the hurricanes, the low birth weight trend exhibited a significant, abrupt decrease by 0.18 women per month, then increased in the post-hurricanes period towards a trend of 0.01 per 100 women per month.

Table 5. No Prenatal Care - Final Time Series Model Results[a]

	USVI				US			
	Coefficient	**Standard Error**	**p-Value**	**95% CI**	**Coefficient**	**Standard Error**	**p-Value**	**95% CI**
Intercept *b0*	5.14	5.43	0.344	(-5.50, 15.78)	-1.95	1.22	0.111	(-4.34, 0.45)
Baseline trend *b1*	0.24	0.24	0.322	(-0.23, 0.71)	0.01	0.04	0.001	(.01, .02)
Level change after hurricanes *b2*	2.51	5.03	0.617	(-7.34, 12.37)	0.00	0.03	0.952	(-.06, .06)
Trend change after hurricanes *b3*	-0.63	0.42	0.132	(-1.45, 0.19)	-0.001	0.00	0.207	(-.01, .00)

[a] The USVI model incorporates one covariate: teen births. The US model incorporates four covariates: AMA, teen births, NH Black, and Hispanic. The full model with the parameters for each covariate can be found in **Appendix C**.

Table 6. Hypertensive Disorders of Pregnancy - Final Time Series Model Results USVI and the US[a]

	USVI				US			
	Coefficient	**Standard Error**	**p-Value**	**95% CI**	**Coefficient**	**Standard Error**	**p-Value**	**95% CI**
Intercept *b0*	2.31	1.23	0.08	(-0.29, 4.92)	2.83	4.811	0.557	(-6.61, 12.26)
Baseline trend *b1*	-0.04	0.05	0.447	(-0.13, 0.06)	0.033	0.015	0.023	(0.00, 0.06)
Level change after hurricanes *b2*	1.14	1.32	0.392	(-1.51, 3.80)	0.050	0.155	0.746	(-0.25, 0.36)
Trend change after hurricanes *b3*	0.07	0.09	0.486	(-0.12, 0.26)	0.014	0.015	0.373	(-0.02, 0.05)

[a] The USVI model incorporates one covariate: teen births. The US model incorporates four covariates: AMA, teen births, NH Black, and Hispanic. The full model with the parameters for each covariate can be found in **Appendix C**.

Table 7. Preterm Birth - Final Time Series Model Results [a]

	USVI				US			
	Coefficient	**Standard Error**	**p-Value**	**95% CI**	**Coefficient**	**Standard Error**	**p-Value**	**95% CI**
Intercept *b0*	7.46	1.84	<.001	(3.86, 11.06)	8.16	4.43	0.066	(-0.52, 16.85)
Baseline trend *b1*	0.00	0.06	0.966	(-0.11, 0.12)	-0.03	0.01	0.035	(-0.06, 0.00)
Level change after hurricanes *b2*	-1.11	1.68	0.508	(-4.41, 2.18)	-0.033	0.12	0.009	(-0.57, -0.08)
Trend change after hurricanes *b3*	0.36	0.13	0.004	(0.11, 0.622)	0.02	0.014	0.090	(-0.01, 0.05)

[a] The USVI model incorporates one covariate: teen births. The US model incorporates four covariates: AMA, teen births, NH Black, and Hispanic. The full model with the parameters for each covariate can be found in **Appendix C**.

Table 8. Cesarean Birth - Final Time Series Model Results [a]

	USVI				US			
	Coefficient	**Standard Error**	**p-Value**	**95% CI**	**Coefficient**	**Standard Error**	**p-Value**	**95% CI**
Intercept *b0*	27.93	3.11	<.001	(21.69, 34.18)	20.68	5.86	0.000	(9.19, 32.17)
Baseline trend *b1*	0.19	0.11	0.084	(-0.03, 0.41)	-0.04	0.02	0.026	(-0.07, -0.01)
Level change after hurricanes *b2*	-2.33	3.17	0.466	(-8.70, 4.04)	-0.40	0.29	0.167	(-0.96, 0.17)
Trend change after hurricanes *b3*	-0.06	0.23	0.786	(-0.52, 0.39)	-0.01	0.03	0.638	(-0.07, 0.05)

[a] The USVI model incorporates one covariate: teen births. The US model incorporates five covariates: AMA, teen births, NH Black, and Hispanic. The full model with the parameters for each covariate can be found in **Appendix C**.

Table 9. Small for Gestational Age - Final Time Series Model Results [a]

	USVI				US			
	Coefficient	**Standard Error**	**p-Value**	**95% CI**	**Coefficient**	**Standard Error**	**p-Value**	**95% CI**
Intercept *b0*	2.33	2.29	0.308	(-2.15, 6.81)	-3.25	1.71	0.057	(-6.60, .10)
Baseline trend *b1*	0.12	0.09	0.217	(-0.07, 0.30)	0.00	0.01	0.800	(-.01, .02)
Level change after hurricanes *b2*	1.71	1.87	0.358	(-1.94, 5.37)	-0.04	0.06	0.536	(-0.16, 0.09)
Trend change after hurricanes *b3*	-0.35	0.17	0.037	(-0.67, -0.02)	-0.01	0.01	0.134	(-0.03, 0.00)

[a] The USVI model incorporates one covariate: teen births. The US model incorporates four covariates: AMA, teen births, NH Black, and Hispanic. The full model with the parameters for each covariate can be found in **Appendix C**.

Table 10. Low Birth Weight - Final Time Series Model Results [a]

	USVI				US			
	Coefficient	**Standard Error**	**p-Value**	**95% CI**	**Coefficient**	**Standard Error**	**p-Value**	**95% CI**
Intercept *b0*	4.98	1.64	0.004	(1.68, 8.28)	1.47	1.71	0.389	(-1.88, 4.82)
Baseline trend *b1*	0.01	0.06	0.898	(-0.10, 0.12)	-0.03	0.01	0.002	(-0.04, -0.01)
Level change after hurricanes *b2*	0.36	1.83	0.846	(-3.33, 4.05)	-0.18	0.07	0.010	(-0.32, -0.04)
Trend change after hurricanes *b3*	0.06	0.18	0.75	(-0.30, 0.42)	0.01	0.01	0.236	(-0.01, 0.03)

[a] The USVI model incorporates one covariate: teen births. The US model incorporates four covariates: AMA, teen births, NH Black, and Hispanic. The full model with the parameters for each covariate can be found in **Appendix C**.

Figure 6. Rate of No Prenatal Care in the USVI and US over Time

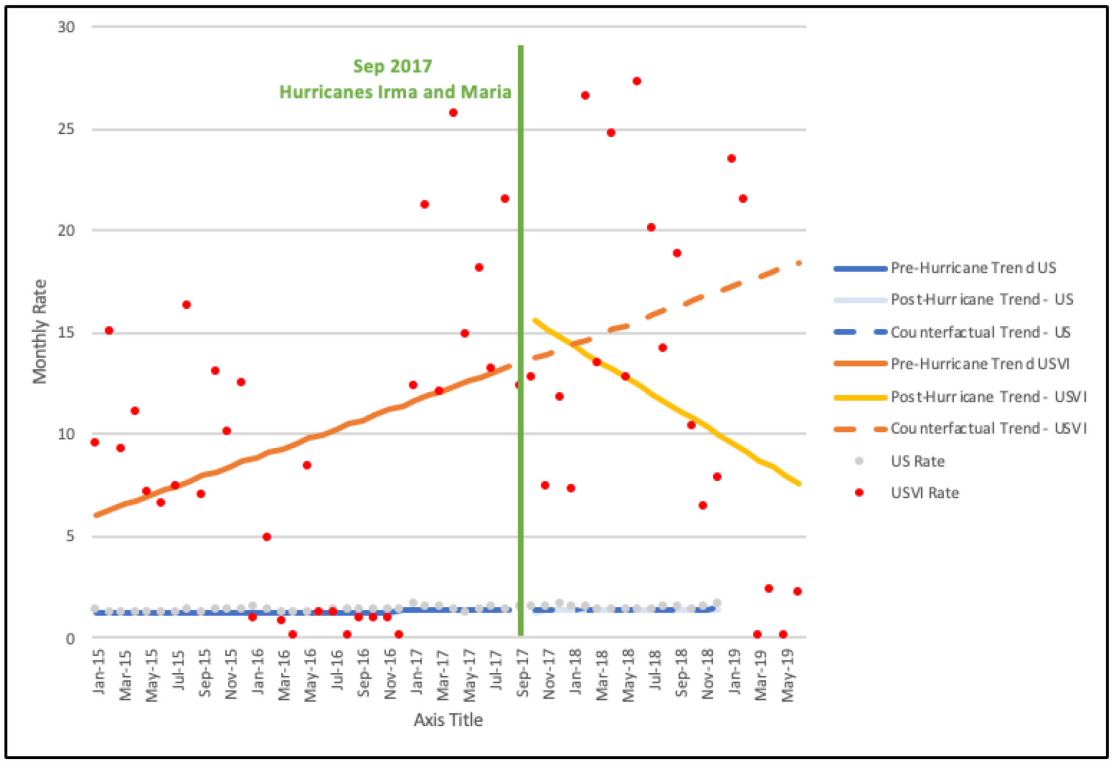


Figure 7. Rate of Hypertensive Disorders of Pregnancy in the USVI and US over Time

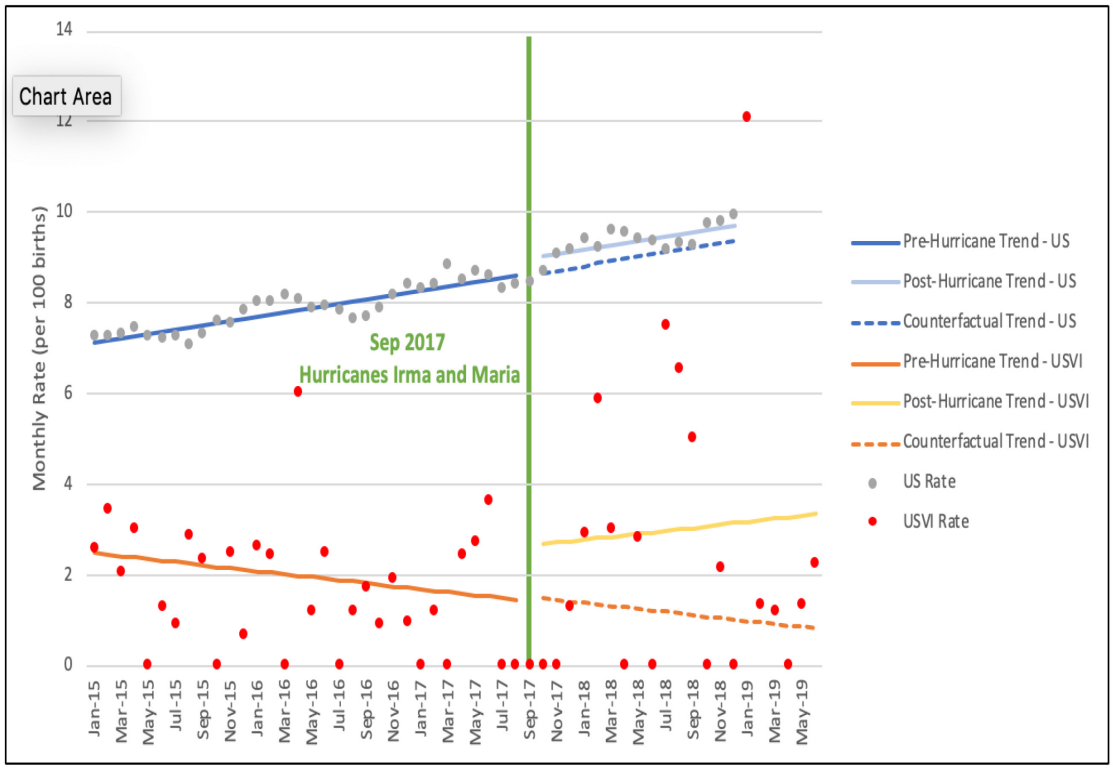


Figure 8. Rate of Preterm Births in the USVI and US over Time

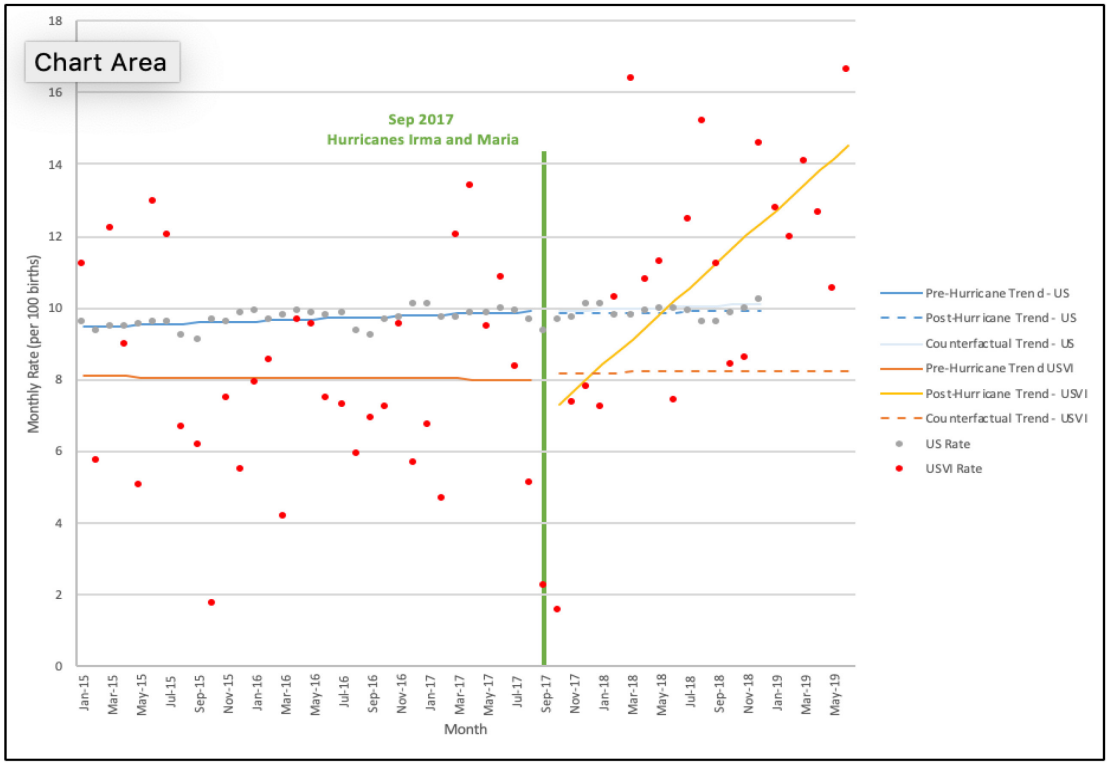


Figure 9. Rate of Cesarean Births in the USVI and US over Time

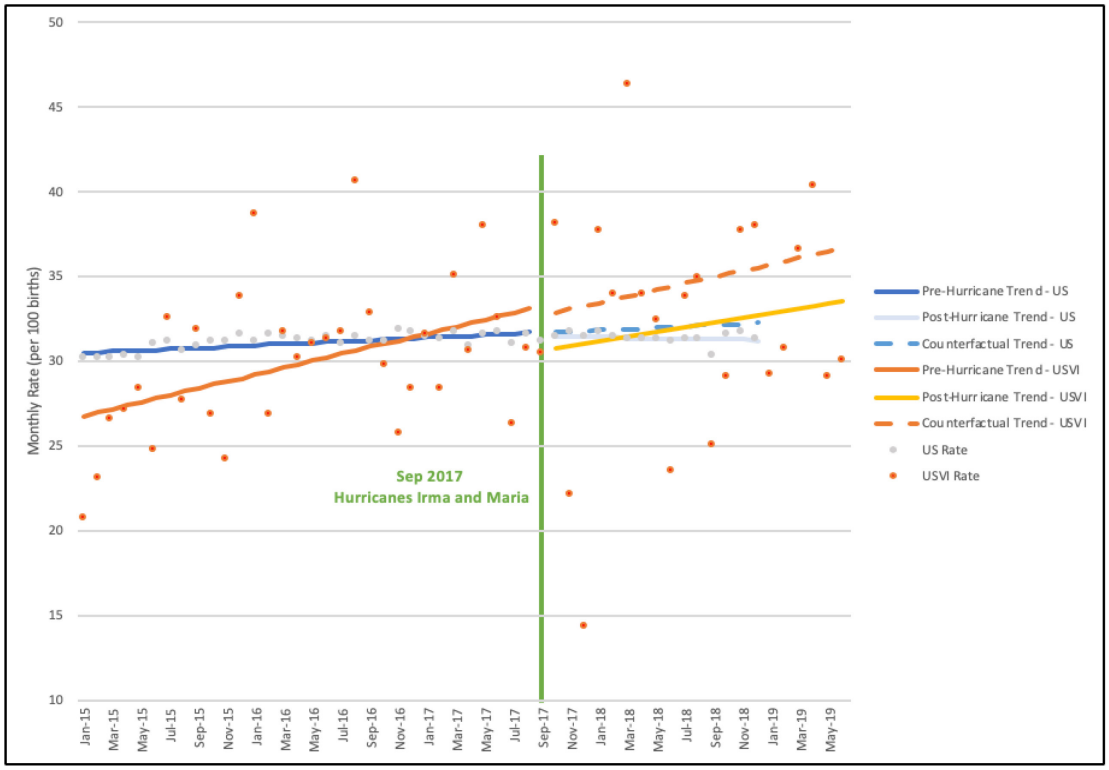


Figure 10. Rate of Small for Gestational Age in the USVI and US

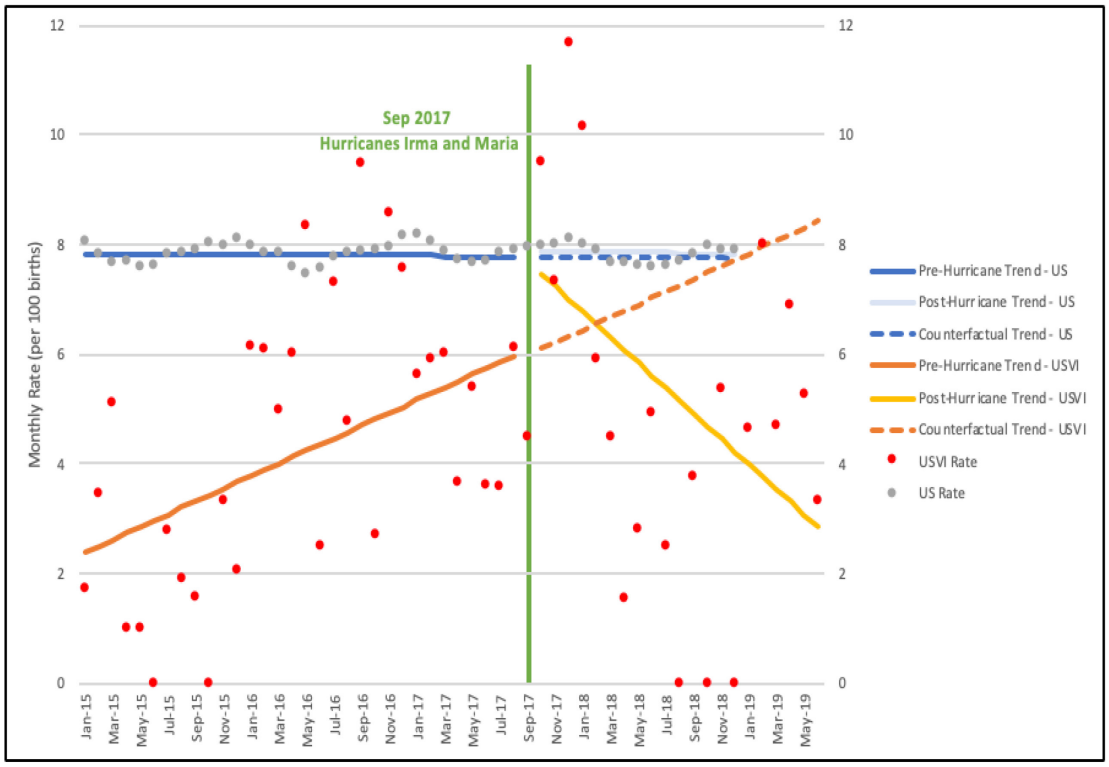
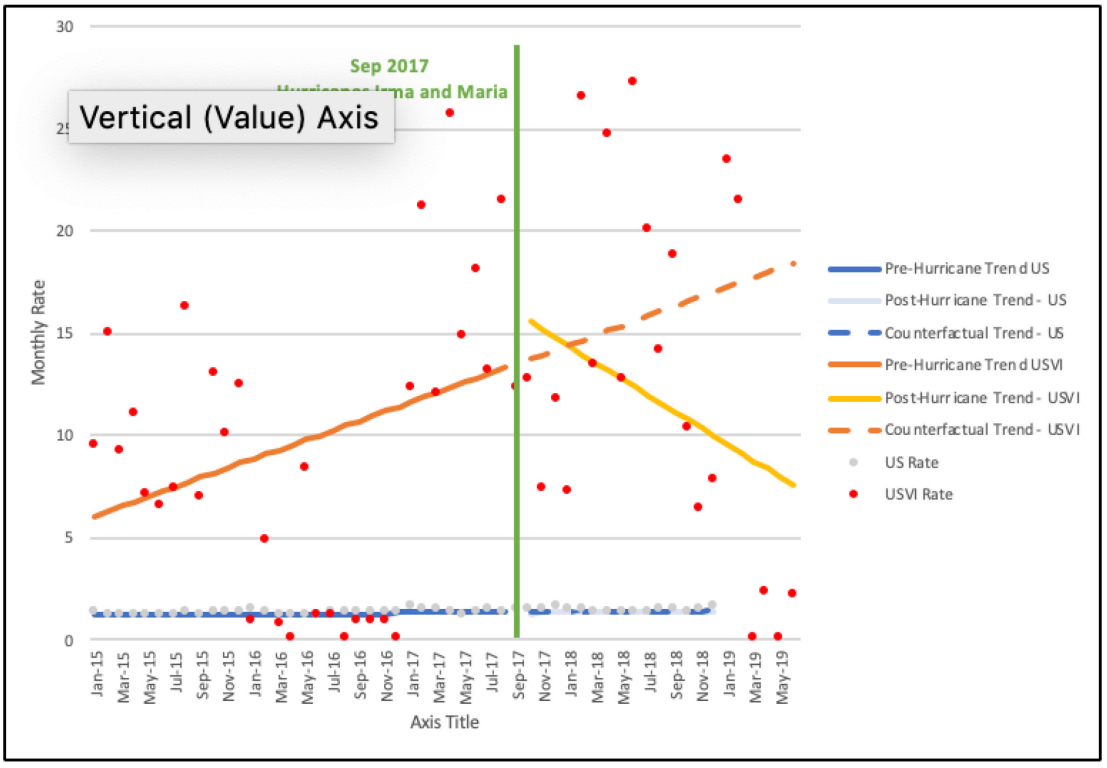


Figure 11. Rate of Low Birth Weight in the USVI and US over Time



Magnitude of Effects

To estimate the magnitude of the effect in the USVI, we compared the unadjusted observed rate of maternal-neonatal outcomes at 21 months post-Hurricanes Irma and Maria with the unadjusted expected (counterfactual) rate of maternal neonatal outcomes at 21 months post-Hurricanes Irma and Maria. When projected across the first 21 months after the hurricanes, we found that there was a 66.04% decrease in observed SGA births over the projected expected rate. Thus, the rate of SGA births is 66.04% lower than what we would have expected had the hurricanes not occurred. For preterm births, our findings indicate that there was an 82.64% increase in observed preterm births over the predicted expected number. In the post-hurricanes period, we also observed nonsignificant increases in the rates of HDP (586.05%) and LBW (23.48%) along with decreases in CB (10.88%) and NPC (58.25%). We conducted similar analyses with the US data and found that the magnitude of difference between the observed and expected rates of each outcome in the US was much lower than those exhibited by the USVI. When projected across the first 15 months after the hurricanes, we found that the observed rate of PTB was 1% higher and the observed rate of LBW was 0.73% than the expected rate had the hurricanes not occurred. In the post-hurricanes period, we also observed nonsignificant increases in the observed rates of HDP (3.6%) in SGA (0.26%) and nonsignificant decreases in NPC (1.34%) and CB (3.08%) over the expected rates.

Table 11. Comparison of Observed versus Counterfactual Monthly Rate at 21 months post hurricanes in the USVI

	Observed Monthly Rate (per 100 births) at 21 months post Hurricanes	Expected (Counterfactual) Monthly Rate (per 100 births) at 21 months post Hurricanes	Percent Difference [(Observed-Expected)/Expected *100]
No Prenatal Care	7.57	18.13	-58.25%
Hypertensive Disorders in Pregnancy	2.95	0.43	586.05%
Cesarean Birth	33.58	37.68	-10.88%
Preterm Birth	14.52	7.95	82.64%
Low Birth Weight[a]	6.31	5.11	23.48%
Small for Gestational Age	2.87	8.45	-66.04%

[a]Due to data availability, the observed and counterfactual monthly rates are calculated at 15 months post Hurricanes.

Table 12. Comparison of Observed versus Counterfactual Monthly Rate at 15 months post hurricanes in the US

	Observed Monthly Rate (per 100 births) at 15 months post Hurricanes	Expected (Counterfactual) Monthly Rate (per 100 births) at 15 months post Hurricanes	Percent Difference [(Observed-Expected)/Expected *100]
No Prenatal Care	1.47	1.49	-1.34%
Hypertensive Disorders in Pregnancy	9.70	9.36	3.6%
Cesarean Birth	31.20	32.19	-3.08%
Preterm Birth	10.07	9.97	1.00%
Low Birth Weight	8.20	8.26	-0.73%
Small for Gestational Age	7.82	7.80	0.26%

Qualitative Results

Participant Characteristics

The sociodemographic, pregnancy, and birth characteristics for the 18 participants are summarized in Table 9. The majority of the participants were over the age of 30 (*n* = 10), Black/African Caribbean (*n* = 11) and not Hispanic (*n* = 15). Half of

the participants (*n* = 9) were never married. Most were employed full-time at the time of the interview (*n* = 12) and less than half reported some college or greater level of education (n=8). Nine of the participants resided on St. Croix at the time of the Hurricanes and the remainder resided on St. Thomas (*n* = 8) and St. John (*n* = 1). All of the participants gave birth full-term (*n* = 18); half gave birth vaginally (*n* = 9) and half gave birth via cesarean (*n* = 9). A majority of participants reported no hypertension in pregnancy (*n* = 13) and a delay or interruption in prenatal care (*n* = 12).

Table 13. Participant Sociodemographic, Pregnancy, and Birth Characteristics

Characteristic	n (%)
Age	
18-24	2 (11.1%)
25-29	6 (33.3)
30-34	7 (38.9%)
35-39	1 (5.6%)
40-44	2 (11.1%)
Race	
Black/African Caribbean	11 (61.1%)
White	4 (22.2%)
Multiracial	3 (16.7%)
Ethnicity	
Hispanic	3 (16.7%)
Not Hispanic	15 (83.3%)
Marital Status	
Never Married	9 (50.0%)
Married	8 (44.4%)
Divorced	1 (5.6%)
Employment	
Not Employed	5 (27.8%)
Part-Time	1 (5.6%)
Full-Time	12 (66.7%)
Education	
Less than High School	5 (27.8%)
High School	5 (27.8%)
Some College	3 (16.7%)

College	2 (11.1%)
Graduate	2 (11.1%)
Post-Graduate	1 (5.6%)
Household Annual Income	
$0-$15,000	3 (16.7%)
$15,000-$25,000	3 (16.7%)
$25,000-$60,000	7 (38.9%)
Greater than $60,000	5 (27.8%)
Island of Residence	
St. Croix (Hurricane Maria)	9 (50.0%)
St. Thomas (Hurricane Irma)	8 (44.4%)
St. John (Hurricane Irma)	1 (5.6%)
Gave Birth in the USVI	
Yes	14 (77.8%)
No	4 (22.2%)
Type of Birth	
Vaginal	9 (50%)
Cesarean	9 (50%)
Timing of Birth	
Full Term	18 (100%)
Pre-Term	0 (0%)
Hypertension	
Yes	5 (16.7%)
No	13 (83.3%)
Delay or Interruption in Prenatal Care	
Yes	12 (66.7%)
No	6 (33.3%)
Low Birth Weight	
Yes	6 (33.3%)
No	12 (66.7%)

Themes

The themes that emerged based on analysis of the interviews and the quantitative results were migration, stress, and resilience. The first theme, migration, discusses how participants weighed the decision of whether to remain on island for birth or to return to the US mainland. The second theme, stress, includes participants' responses about experiencing significant stress as a result of the hurricane. The third

theme, resilience, highlights descriptions of adaptation and transformation after the hurricanes.

Migration "I had to go"

Participants reported that they struggled with the decision to remain in the USVI or to temporarily migrate and go to the US mainland for the remainder of their pregnancy and birth. Some participants wanted to remain on island so that their partners could be present for the birth. Others attributed special meaning to having their child in the islands so they would be a "true Virgin Islander." Many reported that family and friends encouraged them to leave the island to have their baby, even in the face of an otherwise normal pregnancy course. Other participants considered leaving the island because of lack of access to clean water and electricity.

Participants reported having significant concerns about the hospital's capacity. Many participants inquired with their maternity provider or other healthcare workers for guidance on whether the hospital would be a suitable location for giving birth. Participants (n = 3) with higher risk pregnancies ultimately decided to leave the island. Under normal circumstances, USVI hospitals could accommodate these pregnancies. However, given the damage to the hospital and concerns around the hospital's ability to provide quality care, maternity providers explicitly recommended that women with high risk pregnancies leave the island. This participant described the specific guidance they received from their physicians:

> *[My doctor] told me, "I'm not sure what's gonna take place with the hospital." So…any of her patients that she feels are high risk…she was shipping them off to the mainland.*

One participant was experiencing a high-risk twin pregnancy, and her midwife arranged for her to relocate to the mainland United States:

> *My pregnancy was already high-risk because I was carrying twins. They wanted to get the people with more serious problems out based off of how much was damaged, pregnant people and people with other problems…At the time, they didn't have the necessary materials in case my babies were born… [My midwife] kept trying to get us on a mercy flight.*

Stress

The hurricanes generated multiple new stressors and sometimes accentuated pre-existing stressors for participants. Participants were displaced from their homes (*n* = 7), no one had running water or electricity immediately after the storms, and some experienced strain in their family or romantic relationships. Participants described how the hurricanes disrupted their normal lives:

> *I know that I have been more stressed than I [ever] have in my life. Being unstable is really hard.*

> *It was stressful. There were a lot more things we had to think about that we wouldn't have had to think about if the hurricane didn't hit.*

While none of the participants reported having a preterm birth, many were aware that stress can impact pregnancy outcomes. One participant reflected on how stress might have affected her pregnancy:

> *With the stress of everything—she may have come a little early.*

Others directly attributed the stress to outcomes such as exacerbated gestational diabetes or inadequate weight gain:

> *I stopped working…I felt so stressed. And the doctor said, you know, my blood sugar went too high. Maybe stress played a role. So, he just said, 'Take a break." I ended up taking a break until I gave birth.*

I was not eating healthy… I was so stressed out… I wasn't putting on much pounds... I put on only nine pounds --- for my whole entire pregnancy, stress and everything.

Some participants addressed the stress associated with managing the pregnancy alongside the hurricane-related stressors:

It was kind a stressful to figure out how I was going to be pregnant and I was going to be able to do all of these things without proper care if we couldn't get to a doctor and without electricity and without internet, all of those things.

Resilience

Resilience was a significant theme that emerged from the interviews at the individual, household/community, and maternity system levels. Participants described ways they were able to adapt and cope with the recovery environment. Many participants drew on intentional emotional regulation, positive thinking, and prayer:

I was just focused in on being calm the entire time.

I was happy and I was grateful, and I had the perspective of, you know, God's giving it to me, so God will provide. I wasn't worried at all. I was very positive throughout.

Participants who reported enjoying close family and community support praised the positive impact this support had on their mood and on surviving. These participants described the importance of psychosocial support:

I think family is important. That's probably the biggest help you can get. Having people around to tell you that everything is gonna be ok. Everything is gonna get better. I definitely think having people around you plays a big factor.

I just prayed a lot. Being around positive people helped me to kind of break out of it. My husband- even though he's not there, he was there. We talked every day.

Some participants reflected on how the community in the USVI, as opposed to the mainland United States, contributed positively to their recovery experience. One

participant described how the Caribbean culture and its approach to pregnancy and motherhood contributed to her feeling supported:

> *Being in the Caribbean culture, people are very appreciative of motherhood. There's more of a sisterhood. I think that's a positive…Here [you have] the person in the store help you out or talk to the baby for you if she's acting up. If a hurricane hit Philly, I'd, you know, probably had less support from strangers [laughter].*

Other participants noted that, with each hurricane, the territory has learned, adapted, and improved preparedness and response. Reflecting on her experience, this participant compared the varied hurricane recoveries that she has experienced, noting their differences:

> *The hurricane was as bad as [Hurricane] Hugo. But you know, within a month or two, [the island] was already in recovery...We did have a really good recovery turnover after Maria. I cannot say that we didn't because I've been through [Hurricane] Hugo.*

The interviews also highlighted the resilience of the maternity system. Participants reported having the skills and family/community support to cope with short-term disruptions in prenatal care and a lack of hot water in the hospital when they gave birth. Many expressed being satisfied with the care they received from their prenatal providers and the hospitals. This participant discussed her positive birthing experience:

> *I did deliver in the hospital, in labor and delivery. And thankfully, that was one of the places in the hospital that was still in tip-top shape. The rooms were nice. It was clean. There were really no big smells because there were a lot of places that smelled like mold after the hurricane, but I had no problems. My delivery was perfect. I had no issues.*

Discussion

Our study is the first, to our knowledge, to quantify the maternal and neonatal effects of Hurricanes Irma and Maria. The findings demonstrated that in the post-

hurricanes period, the trend of SGA births declined by 0.35 births per 100 births, while the trend of PTB increased by 0.36 births per 100 births. There were no significant findings related to the change in trend of births characterized by NPC, HDP, CB, and LBW. None of the outcomes exhibited any changes in level in the post-hurricanes period.

Previous evidence of post-hurricanes pregnancy and birth outcomes had not examined SGA (N. Jeffers & N. Glass, unpublished data, 2020). Therefore, the study's finding of a decline in the rate of SGA post-hurricanes provided novel information regarding the impact of hurricane exposure on birth outcomes. Within the wider disaster literature, the findings regarding SGA are not consistent. After September 11th, the rate of SGA increased significantly,[41] but after a major North Dakota Flood, rates of SGA among affected women did not change significantly.[42] When we considered the results of the qualitative phase to better understand the quantitative findings, we identified a possible explanation for our results. The migration of women with higher risk pregnancies towards the US mainland might help explain the decrease in SGA over time. Although the hospital continued to manage normal pregnancies and births immediately after the storm, concerns regarding the capacity of the hospital encouraged women with high risk pregnancies and other concerns to leave the territory. The qualitative findings support this explanation (see the matrix of qualitative and quantitative findings displayed in Table 14). Participants reported that some women with high risk pregnancies were medically evacuated out of the USVI and others were encouraged to leave on mercy flights in the weeks and months after the hurricanes. Healthcare providers not only encouraged them to leave the island, but some also

proactively assisted in coordinating efforts to arrange for their departure as well. While prior qualitative studies have discussed pre- and post-disaster evacuation,[16,18] they have not addressed temporary post-disaster migration for delivery. Future research is necessary to further elucidate the relationship between hurricane exposure and small for gestational age.

Table 14. Matrix of Quantitative and Qualitative Findings

Quantitative Findings	Qualitative Theme	Inference	Exemplary Quotes
Significant decrease in the trend of SGA after the hurricanes.	Migration "I had to go."	Increases in medical evacuations for women with high risk pregnancies may account for decreases in the trend of SGA.	"Everyone told me, all my friends and family told me I need to get off island to have the baby." "[My doctor] did say "I do advise you to…relocate until after the baby is born." "[[My doctor] told me, 'I'm not sure what's gonna take place with the hospital.' So…any of her patients that she feels are high risk…she was shipping them off to the mainland." "I wasn't taking any chances with the birth…The fact that we had no water home and no power…I couldn't have done it." "There was a lot of chaos…I can't deal with limited resources. I [had] to go" "[My midwife] told me I had to go…I really didn't want to deliver on the island because anything could've happened. I didn't want to take any chances, so I took the opportunity to leave." "My pregnancy was already high-risk because I was carrying twins. They wanted to get the people with more serious problems out based off of how much was damaged, pregnant people and people with other problems…At the time, they didn't have the necessary materials in case my babies were born… [My midwife] kept trying to get us on a mercy flight."
Significant increase in the trend of preterm birth after the hurricanes.	Stress - "I felt so stressed"	Significant increase in trend of preterm birth after the hurricanes may be due to the impact of stress.	"I was a lot more stressed than a normal pregnant person, with all those factors. You're kind of depressed a little bit. I mean, I suppressed a lot of emotion." "With the stress of everything—she may have come a little early." "It was stressful. There were a lot more things we had to think about that we wouldn't have had to think about if the hurricane didn't hit." "My mental health definitely took a toll with the hurricane."

			"I stopped working…I felt so stressed. And the doctor said, you know, my blood sugar went too high. Maybe stress played a role. So, he just said, 'Take a break." I ended up taking a break until I gave birth" "I was not eating healthy… I was so stressed out… I wasn't putting on much pounds... I put on only nine pounds --- for my whole entire pregnancy, stress and everything." "It was kind a stressful to figure out how I was going to be pregnant and I was going to be able to do all of these things without proper care if we couldn't get to a doctor and without electricity and without internet, all of those things."
No significant level changes in any outcome. No significant changes in the trend of HDP, CB, and LBW.	Resilience - "We [had] a really good recovery"	Despite experiencing significant stressors, resilience may have prevented significant abrupt changes in the majority of the outcomes of interest.	"I was just focused in on being calm the entire time." "I was happy and I was grateful, and I had the perspective of, you know, God's giving it to me, so God will provide. I wasn't worried at all. I was very positive throughout." "I just prayed a lot. Being around positive people helped me to kind of break out of it. My husband- even though he's not there, he *was* there. We talked every day." "Being in the Caribbean culture, people are very appreciative of motherhood. There's more of a sisterhood. I think that's a positive…Here [you have] the person in the store help you out or talk to the baby for you if she's acting up. If a hurricane hit Philly, I'd, you know, probably had less support from strangers [laughter]." "I think family is important. That's probably the biggest help you can get. Having people around to tell you that everything is gonna be ok. Everything is gonna get better. I definitely think having people around you plays a big factor." "I think it was great. I had a lot of attention. I asked for things and they got it. It seemed like nothing was amiss. I don't know what it would have been like anywhere else, but it seemed like they had everything prepared." "The hurricane was as bad as [Hurricane] Hugo. But you know, within a month or two, [the island] was already in recovery...We did

> have a really good recovery turnover after Maria. I cannot say that we didn't because I've been through [Hurricane] Hugo."
>
> "I did deliver in the hospital, in labor and delivery. And thankfully, that was one of the places in the hospital that was still in tip-top shape. The rooms were nice. It was clean. There were really no big smells because there were a lot of places that smelled like mold after the hurricane, but I had no problems. My delivery was perfect. I had no issues."

The trend of PTB increased significantly after the storm. This finding is consistent with those of other studies conducted in the United States[5,6,8,43] and Australia,[4] which indicated that there is an association between hurricane exposure and PTB. Researchers have theorized that stress leads to immune dysregulation and an increase in inflammatory cytokines, both of which may prematurely ignite the parturition pathway.[44] A potential explanation for the findings in our ITS is that the stress experienced after Hurricanes Irma and Maria may have contributed to the increased rate of PTB over time. Participants in the qualitative phase reported a sudden increase in daily life stressors during the hurricane recovery process. Participants of other qualitative studies conducted in Louisiana after Hurricane Katrina[16] and the Philippines after Cyclone Yasi[4] also reported significant post-hurricane stress. Survivors of Hurricane Katrina were similarly concerned about how stress would impact their pregnancy and baby.[16] Women who endured Cyclone Yasi also reported difficulty coping with the loss of belongings and disruptions in prenatal care.[18] Hurricane preparedness and response policies should acknowledge the potential role of stress in maternal-neonatal outcomes. Hurricane response plans should also include short- and

long-term mental health interventions to help pregnant women cope with stress and mental health disorders such as depression, anxiety and PTSD post-hurricane.

The variables of HDP, CB, and LBW exhibited no significant changes in level or trend in the post-hurricanes period. Hypertensive disorders have previously been associated with hurricane exposure.[4,6,7] The research on LBW is mixed.[7–11,45,46] Based on the results of the present study, it is not immediately clear why the hurricanes may have adversely impacted PTB while not impacting other outcomes such as HDP or LBW. However, insights from the qualitative portion of the study indicate considerable resilience exhibited by individuals, the household and community, and the maternity system. Participants reported components of resiliency including the use of faith, positive thinking, and a heavy reliance on family and friends for support. Community norms around supporting pregnant women, accumulating community experience with hurricane recovery, and the ability of the maternity system to continue providing high quality care were also notable findings. Despite experiencing stress, then, it is possible that the adaptive capacity of the individuals, the larger community, and the healthcare system was, overall, a protective factor. While previous research has highlighted the importance of post-disaster resilience for individuals,[47,48] communities,[49,50] and health systems, little extant research has addressed how resilience might impact maternal-neonatal outcomes, specifically. Future research should include investigate how resilience may moderate or mediate maternal-neonatal outcomes.

After completing the ITS analysis of the USVI data, the authors conducted a stratified analysis, using the United States as a comparison group. We found a significant change in the levels of PTB and LBW after September 2017. In the United

States, the levels of PTB and LBW decreased abruptly in the first month in the post-hurricanes period as compared to the pre-hurricanes period. We would have expected to see no significant change in level or trend of these outcomes for the United States, since September 2017 is theoretically a random date in that context. Since the United States, as a comparison group, exhibited different significant changes than the USVI, it is possible that we did not account for confounders, such as major policy or practice recommendations from the American Congress of Obstetricians and Gynecologists (ACOG). However, a review of the policy and practice updates and recommendations published by ACOG in 2017 yielded no obvious major changes that would have coincided with Hurricanes Irma and Maria. It is possible that there was a true level change in PTB and LBW in the United States. United States pregnancy and birth outcomes are analyzed on a yearly basis, and small but significant changes do occur from year to year, even in the absence of changes in practice or policy. However, another potential explanation is that data from the United States was so large that it was overpowered. The US trend in total number of monthly births is large and stable, with little variability. Therefore, the data exhibits high power to detect extremely small differences in US birth data, while the USVI data is only powered to detect moderate or large differences.[51] When you compare the results in Table 11 and Table 2, its apparent that the USVI exhibited much larger percent differences when comparing the observed and expected rates for each outcome in the post-hurricane period. In contrast, the US changes were very small and thus, may not be clinically meaningful.

Limitations

The quantitative phase of this study has several limitations. First, due to the timing of the study and delays in receiving final vital statistics and birth data, we analyzed less than 2 years of data in the post-hurricanes period. It is possible that analyzing data for at least 24 months or more might have yielded different results. Second, ITS design is characterized by several known limitations that potentially impact the validity of the analysis.[52] The interrupted time series design cannot account for changes in the population over time. Thus, if the population giving birth prior to the hurricanes was fundamentally different than the population that gave birth after the hurricanes, it is possible that any significant findings are due to those population shifts as opposed to a direct causal impact by the event of interest. As seen with the results from the SGA outcome, it is possible that this occurred in our analysis as many high risk women may have left the territory after the hurricanes. Third, it is also important to consider that data quality in the USVI may have changed after Hurricanes Irma and Maria, thus impacting the results. Incomplete medical documentation in the USVI after the Hurricanes has been previously cited as a concern,[2] and it is possible that our findings were actually due to changes in instrumentation. If the data collection or recording techniques changed in the post-hurricanes period, it is possible that any findings, whether significant or not, may be attributed to these changes as opposed to the effect of the hurricanes. Fourth, while ITS is a powerful design for estimating longitudinal causal impact, it can ultimately only provide inference regarding temporal associations.

Limitations also exist in the qualitative phase. The majority of participants remained in the USVI to give birth and only 4 migrated to the mainland. Therefore, the

predominant narratives were of those that decided to stay in the territory. It is possible that the people that left the USVI were different than the people that stayed and that we failed to gather unique perspectives and experiences which could have further elucidated the quantitative findings. Given the narrow purposive sample, that overall generalizability to the entire pregnant population in the USVI is limited.

Conclusion

Communities threatened by cyclical hurricanes must consider the maternal and neonatal health consequences associated with exposure to these natural disasters. The results of this study indicate that, in the USVI, Hurricanes Irma and Maria in September 2017 were associated with a decrease in the trend of SGA. Interviews with women who were exposed to these hurricanes during pregnancy revealed that post-hurricanes migration of women experiencing high risk pregnancies might account for these significant decreases. The results also indicate an increase in the rate of PTB in the post-hurricanes period. Women reported high levels of stress, a potential contributing factor to PTB that may explain the increasing rates of PTB in the territory. Additional research is necessary to further confirm this relationship and to understand the mechanisms that drive it. In this study, several outcomes appeared resilient to the known negative health impacts by the Hurricanes. Resilience at individual, community, and health system levels may be protective. Ultimately, the results of this study provide the USVI Department of Health, local hospitals, and maternity providers with valuable insight regarding hurricanes exposure and its maternal-neonatal effects, potentially

guiding hurricanes preparedness and response policies to mitigate future adverse outcomes.

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CHAPTER 5: SYNTHESIS/DISCUSSION

Introduction

Hurricanes Irma and Maria made landfall in the USVI in September 2017. As an American territory in the Caribbean, the USVI is vulnerable to cyclical hurricane activity with each annual hurricane season. Hurricane exposure during pregnancy places women at additional risk of adverse maternal-neonatal outcomes including preterm birth,[1–3] cesarean birth,[4] low birth weight,[5–7] neonatal morbidity[8] and fetal death.[9] However, there is limited research about maternal-neonatal outcomes after hurricane exposure in the Caribbean. In the context of human-induced climate change, the threat of the most intense hurricanes is projected to grow,[10,11] increasing the urgency to understand how these hurricanes will impact maternal-neonatal health in the USVI.

Using a convergent, mixed-methods design,[12] I set out to understand the population- and individual-level maternal-neonatal health effects of hurricane exposure on women in the USVI who were exposed to Hurricanes Irma and Maria during pregnancy. A Conceptual Framework for Maternal-Neonatal Health Risk and Resilience following Hurricane Exposure (see Figure 2) guided the study. The quantitative phase of the study utilized an interrupted time series analysis to estimate the longitudinal causal impact of Hurricanes Irma and Maria on six outcomes: no prenatal care, hypertensive disorders of pregnancy, preterm birth, cesarean birth, low birth weight and small for gestational age. A purposive sample of 18 participants were interviewed for the qualitative phase.

Specific Aims

The specific aims of this dissertation were:

Aim 1 (Quantitative): Examine if the pattern of adverse maternal and neonatal outcomes in the USVI changed after severe hurricane exposure by conducting an interrupted time series regression analysis of aggregate birth data from the USVI Department of Health.

Hypothesis 1: The level and trend of hypertensive disorders of pregnancy, cesarean delivery, preterm birth, small for gestational age newborns, and no prenatal care will increase in the post-hurricane period as compared to the pre-hurricane period.

Aim 2A. (Qualitative): Among women who were pregnant during Hurricanes Irma and Maria**,** explore individual experiences of managing pregnancy and giving birth in the months after the hurricanes.

The following topics will be explored through in-depth interviews:

(1) Hurricane-related deficiencies in prenatal or obstetric care access, utilization, and quality that are known contributors to adverse maternal and neonatal outcomes.

(2) Individual, interpersonal, community, health system, societal, and structural factors that contributed to maternal and neonatal health risk and resiliency.

Aim 2B. (Mixed Methods). Understand the pattern of maternal and neonatal outcomes after severe hurricane exposure within the context of in-depth descriptions of risk and resiliency.

Summary of Findings by Aim

Aim 1

We hypothesized that the immediate level and the trend of post-hurricane adverse maternal and neonatal outcomes would increase in the post-hurricane period as compared to the pre-hurricane period. We utilized a segmented regression analysis. After accounting for any autocorrelation and seasonality present in the birth data, we ran a segmented regression analysis separately for each variable.

Our findings (see Tables 5-10) indicate that there was a decrease in the trend in small for gestational age (B = -0.347; *95% CI,* [-0.67, -0.02]; *p* = .037) in the post-hurricane period. There was an increase in the trend for preterm birth (B = 0.36; *95% CI,* [-1.45, 0.19]; *p* = .04) in the post-hurricane period. The remaining variables, no prenatal care (B = -0.63; *95% CI,* [-1.45, 0.19]; *p* = .132), hypertensive disorders of pregnancy (B = 0.07; *95% CI*, [-0.12, 0.26]; *p* = 0.486), cesarean birth (B = -0.06; *95% CI*, [-0.52, 0.39]; *p* = 0.786) , and low birth weight (B = 0.06; *95* CI, [-0.30, 0.42]; *p* = 0.75) did not experience any trend changes in the post-hurricane period. There were no abrupt changes in level immediately after the Hurricanes for after the Hurricanes for no prenatal care (B = - 2.51; *95% CI*, [-7.34, 12.37]; *p* = 0.617), hypertensive disorders of pregnancy (B = 1.14; *95% CI*, [-1.51, 3.80]; *p* = 0.392; preterm birth (B = -1.11; *95% CI*, [-4.41, 2.18]; *p* = 0.508), cesarean birth (B = -2.33; *95% CI*, [-8.70, 4.04]; *p = 0.466)*, low birth weight (B = 0.36; *95% CI*, [-3.33, 4.05]; *p* = 4.05) and small for gestational age (B = 1.71; *95% CI*, [-1.94, 5.37]; *p* = 0.358).

We utilized a comparison model to strengthen the validity of the study. None of the outcomes in the US exhibited any changes in trend in the post-hurricanes period.

However, PTB (B = 0.033; *95% CI*, [-0.57, -0.08]; *p* = 0.009) and LBW (B = -0.18; *95% CI*, [-0.32, -0.04]; *p* = 0.010), exhibited significant abrupt changes in level immediately after Hurricanes Irma and Maria in September 2017. Analyses of abrupt level changes immediately after the storms for NPC, HDP, CB, and SGA did not yield any significant findings. We did not expect to see any significant findings in the comparison model. However, given the large sample size, we suspect that the US sample was overpowered and that these findings are not clinically significant, giving confidence to the ITS results for our USVI model.

Aim 2A

We explored the experience of pregnancy and birth among women in the USVI who were exposed to Hurricanes Irma and Maria. Utilizing the study's conceptual framework (see Figure 2) as a guide, in our analysis of the interviews, themes emerged that identified components of risk and resiliency associated with maternal hurricane exposure at three interrelated levels of influence: individual, household/community, and system. At the individual level, women coped with a sudden and significant increase in stress and with a disruption in access to nutritious food. Women described components of resilience including personal coping methods such as prayer, faith, and positive thinking. At the household/community level, women dealt with environmental and physical hazards that put them or their pregnancy in danger and a minority also noted that they had a noticeable lack of support from friends and family. However, most noted that they had abundant tangible and non-tangible support from friends, family, neighbors and coworkers. Within the maternity system, women described a condemned

hospital, difficulty contacting their maternity providers and interrupted maternity care. Some women experiencing high risk pregnancies were advised or assisted by their maternity provider to leave the island for the remainder of their pregnancy and to relocate to the mainland US out of concern for the hospital's diminished capacity. Some noted the lack of supplies and hot water that negatively impacted their birthing or postpartum experiences. The majority spoke positively about their birth experience, the kindness and skill of the nurses, midwives, and obstetrician-gynecologists, the infrastructure of the labor and birth floor, and the overall quality of the care they received.

Aim 2B

Through integration of the qualitative and quantitative data, (see Table 14), our findings suggest that decreases in trend of the rate of small for gestational age may be due to the migration of women with high risk pregnancies to the US mainland prior to birth. The increase in trend of the rate of preterm birth might be attributed to the significant stress experienced by pregnant women after the Hurricane. This would be consistent with recent research that has investigated the role of stress in promoting preterm birth.[13] Most of the outcomes of interest (NPC, HDP, CB, LBW) did not exhibit any significant changes in level or trend. The protective role that resilience plays at the individual, household/community, and maternity system levels may explain these findings.

Discussion

Practice Implications

It is critical that health professionals and institutions providing and facilitating maternity care understand the potential impact of hurricane exposure, as a stressor, to the pregnant woman and her fetus. With this understanding, maternity providers in the USVI that live in threat of hurricane exposure should develop hurricane preparedness and response plans. Private providers including midwives and obstetrician-gynecologists, hospitals, and the Department of Health should develop site-specific hurricane preparedness and response plans. The hospital's plans should incorporate leaders from nursing, midwifery, and obstetrics and gynecology. These plans must include anticipatory guidance to pregnant women regarding hurricane safety and preparation. It should also include a communication plan that will be executed prior and after the Hurricane. This communication plan should include several modalities including text alerts, emails and secure messages, and radio announcements (with coordination from local government and radio stations). It will be critical for offices to plan in advance to maintain continuity of prenatal and postpartum care, facilitate the transfer of women with high-risk pregnancies, and access electronic health records. They should anticipate compromised electricity and impaired telecommunications and wireless/internet access. Finally, the post-hurricane plan should also include resources and referrals for mental health resources to support women's peripartum mental health needs.

Policy Implications

The USVI should develop, practice, and execute a territory-wide maternal-infant health disaster policy and plan. This should be a coordinated effort that includes nurses, midwives, obstetrician-gynecologists, the USVI Department of Health and the hospitals.

Maternity providers should be required to demonstrate that they have hurricane preparedness and response plans in place for their practice setting. The DOH and hospitals should have a communication policy to deliver critical maternal health information to the people of the USVI. It will also be critical to implement a clear policy and plan to evacuate high risk pregnant women out of the USVI in the weeks and months after a severe hurricane. Finally, the territory wide policy should incorporate required periodic simulations to increase provider and institution familiarity and comfort with the plans.

Recommendations for Future Research

The integrative review identified that the body of research examining perinatal health effects of hurricane exposure is characterized by a diverse range of research methods. Future research should explore optimal methods for measuring hurricane exposure on the population- and individual-level. Researchers should also focus on identifying if trimester of exposure is a significant mediating factor in the impact of hurricane exposure on maternal-neonatal outcomes. There is evidence that the severity of the hurricane exposure may be associated with adverse outcomes. However, given data restrictions, this study did not attempt to link individual exposure to outcome. Future research should attempt to understand how an individual's experience might put them at more or less risk for adverse maternal-neonatal outcomes. Finally, this dissertation study provided an in-depth look at women's experiences but it would be helpful to understand the nuances of preparation and response from the perspective of maternal-infant health professionals. Future researchers should conduct interviews with nurses, obstetricians-gynecologists, nurse-midwives, and administrators at the hospital

and the Department of Health. In particular, for nursing science, it would be key to understand the gaps that exist in precluding clinician readiness, and how nurses and advanced practice nurses, including midwives, can prepare and respond to hurricanes and their associated perinatal health impacts.

Conclusion

This research experience provided me with the opportunity to examine, quantitatively and qualitatively, the impact of Hurricanes Irma and Maria on the maternal-neonatal health and outcomes in the USVI. Hurricanes Irma and Maria did make a significant impact on the maternal-neonatal outcomes and on the experience of pregnancy and birth among women in the USVI. While the rate of small for gestational age decreased significantly after the Hurricanes, there was a significant increase in the rate of preterm birth. Narratives of stress, loss of support, traversing environmental and physical hazards, and difficulty in maintaining continuity of prenatal care were mitigated by stories of resilience that focused on coping, coming together among families and the larger community, and a responsive maternity system. Continuing research will undoubtedly help us to understand how we can better mitigate poor outcomes and improve the health of pregnant women weathering future hurricanes.

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Appendices

Appendix A: Interview Guide and Demographic Questionnaire

Interview Guide

- Before Hurricanes Irma/Maria, what were your expectations for this pregnancy?
    - Prompts:
        - Prenatal care
        - Birth process/care
        - Managing stress
- In the days leading up to the hurricanes, what sort of concerns did you have about your pregnancy?
    - Probe: How did you cope with (insert concern listed above)? Repeat as necessary
    - Probe: What preparations did you make to deal with (insert concern listed above)? Repeat as necessary
- Tell me about the night that Hurricane Irma/Maria hit. What was that like for you?
- When thinking about concern for your pregnancy and other potential concerns, such as safety for your family, how did you determine what to prioritize?
- In the days and weeks after the Hurricane, what was it like to get the care that you needed for your pregnancy?
    - Prompt for impact of hurricane on access to and quality of:
        - Prenatal and birth care
        - Emergency services
        - Social services and programs
        - Sanitation
        - Food/clean water
        - Electricity
- What actions did you take to make sure you were receiving adequate care for the pregnancy?
- What made it hard for you, as a pregnant woman, to get through the hurricane?
    - Prompts:
        - Housing loss/Displacement
        - Job loss?/Socioeconomic decline
- What complications did you experience during your pregnancy and birth?
    - Prompts:
        - Obstetric complications
        - Diseases and infections
- What was it like to manage your pregnancy along with your other concerns of [insert concerns previously listed by research participant]?
- What impact, if any, did the Hurricanes have on your health?
    - Prompts
        - Pregnancy health
        - General health

- What were some of the resources you used to help you meet your needs?
    - Prompts
        - Family?
        - Friends?
        - Social Programs (WIC, Healthy Start, TANF, Disaster Relief Funds)
        - Disaster Emergency Support
        - Shelter
- How were your expectations for your pregnancy different from what you experienced?
    - Prompts:
        - Prenatal care
        - Birth process/care
        - Managing stress
- If multiparous: What were some of the differences you experienced between your prior pregnancies and this pregnancy?
    - Prompts:
        - Prenatal care
        - Birth process/care
        - Managing stress
- What impact do you think that living in a US territory may have had on your experience of pregnancy and birth during and after the Hurricanes?
- What might help other pregnant individuals in the future to successfully cope with the changes that come along with dealing with a severe hurricane while pregnant?
- What resources should be available to pregnant women during severe hurricanes?
- Is there anything else you feel is important to tell us about your experience with pregnancy and birth during and after the hurricanes?

Demographic Questionnaire

1. Demographic Questions:
    a. What is your age? _____
        i. Prefer not to answer
    b. What is your race/ethnicity?
        i. African Caribbean/Black
        ii. Hispanic/Latino
        iii. Asian
        iv. Arab
        v. Caucasian
        vi. Prefer not to answer
    c. What is your gender?
        i. Male
        ii. Female
        iii. Transgender
        iv. Nonbinary
        v. Prefer not to answer
    d. What is the highest level of education you have completed?
        i. Less than High School
        ii. High School Diploma/GED
        iii. College/University Degree
        iv. Graduate Degree (Master's)
        v. Post-graduate degree (PhD)
        vi. Prefer Not to Say
    e. Describe your employment status?
        i. Part-Time
        ii. Full-Time
        iii. Prefer Not to Say
    f. What is your marital status?
        i. Married
        ii. Never Married
        iii. Widowed
        iv. Separated
        v. Prefer Not to Say
    g. What is your household income?
        i. $0-15,000
        ii. $15,001-25,000
        iii. $25,001-60,000
        iv. Greater than $60,000
        v. Prefer Not to Say
    h. What island did you live on when Hurricanes Irma and Maria hit?
        i. St. Croix
        ii. St. Thomas
        iii. St. John

2. Pregnancy and Birth Questions
    a. What was your expected due date? _____
        i. I don't know
        ii. Prefer not to answer
    b. What was your actual date of delivery? _____
        i. I don't know
        ii. Prefer not to answer
    c. A full-term birth is when a baby is born at 37 weeks or greater. Did you have a full-term birth?
        i. Yes
        ii. No
        iii. I don't know
        iv. Prefer not to answer
    d. A preterm or premature birth is when a baby is born before 37 weeks. Did you have a preterm birth?
        i. Yes
        ii. No
        iii. I don't know
        iv. Prefer not to answer
    e. How much did your baby weigh at birth?
        i. _____
        ii. I don't know
        iii. Prefer not to answer
    f. Did you experience any delay or interruption in your regular prenatal care?
        i. Yes
        ii. No
        iii. I don't know
        iv. Prefer not to answer
    g. How many prenatal visits did you have?
        i. _____
        ii. I don't know
        iii. Prefer not to answer
    h. During your pregnancy were you ever told you had high blood pressure or pre-eclampsia?
        i. Yes
        ii. No
        iii. I don't know
        iv. Prefer not to answer
    i. When you gave birth, was your baby born…?
        i. Vaginally
        ii. Vaginally – Vacuum
        iii. Vaginally - Forceps
        iv. By cesarean
        v. I don't know
        vi. Prefer not to answer

Appendix B: Codebook

1 Fear of another hurricane
2 Overwhelm
3 Speaking Up
4 Resilience
4.1 Maternity System Resilience
4.2 Growth
4.3 Bond
4.4 Coping
4.4.1 Getting on with it
4.5 Community Resilience
5 Danger or Emergency
6 Good Quote
7 Past Hurricane Experience
8 Impact on Family/Friends/Relationships
9 Competing Priorities
10 Recommendations
10.1 Support
10.2 Future Coping Mechanisms
10.3 Information
10.4 Leave
10.5 Pre Hurricane Guidance for Pregnant Women
11 Impact of Living in a US Territory
11.1 Lack of publicity to USVI
12 Pregnancy and Birth
12.1 Left Island for Birth/Medical Care
12.2 Complications

12.3 Zika
12.4 Stay or Leave
12.5 Experience at Hospital
12.5.1 Opinion of Care
12.5.2 Low Supplies
12.5.3 Hospital Damage/Condemnation
12.6 Birth
13 Post-Hurricane
13.1 Damage to Home
13.2 Taking Stock
13.3 Employment
13.3.1 Not Helpful
13.3.2 Helpful
13.4 Left Island Temporarily
13.5 Pediatric Care
13.6 Lack of Support from Friends/family
13.7 Impact on Hours and Processes
13.8 Postpartum Care
13.9 Caring for Child
13.10 Poor Communication
13.11 Displacement
13.12 Support from Fam and Friends
13.13 Financial
13.14 Post-Hurricane Food & Water
13.15 Lack of Electricity
13.16 Resources
13.16.1 Lack of items
13.16.2 Unable to Benefit
13.16.3 WIC/Other Social Services
13.16.4 Disaster Resources
13.17 Impact on Health

13.17.1 Sought mental health therapy
13.17.2 Stress
13.17.2.1 In Utero Stress
13.17.3 Sadness or Depression
13.18 Prenatal Care Post-Hurricane
13.18.1 Contacting OB Office/Provider
13.18.2 Delay/Interruption in PNC
13.18.3 Damage to OB Provider Office
13.19 Impact of Hurricane on Pregnancy Perception
13.20 What Made It Hard
14 Pre-Hurricane
14.1 Wasn't going to be as bad
14.2 Plans for Birth
14.3 Finding a Safe Place to Stay
14.4 Expectations
14.5 Preparing
14.6 Pre-Hurricane Concerns
15 Lines
16 Hurricane Irma-STX or Maria-STT
17 Night of Hurricane
17.1 Damage to House

1 Fear of another hurricane

2 Overwhelm

Narratives by participants that describe strong feelings of being overwhelmed by specific aspects of the hurricane recovery. They may indicate that a particular stressor or circumstance was too great to manage effectively. This may include descriptions of purposeful inaction or avoidance as a result of the feelings of overwhelm.

3 Speaking Up

Ways in which the participant stated that they advocated for themselves, the pregnancy or their child.

4 Resilience

Descriptions of resilience that include exemplar quotes that reflect: “the capacity of a dynamic system to adapt successfully to disturbances that threaten the viability, the function, or the development of that system.”

4.1 Resilience\Maternity System Resilience

Descriptions of the ways in which the healthcare system responded to the impacts of the hurricane in ways that allowed it to meet the needs of the pregnant population. This may include actions by hospitals, clinics/health care centers, or individual providers.

4.2 Resilience\Growth

Participant perceptions that they experienced personal growth as a result of what they experienced with the hurricanes.

4.3 Resilience\Bond

Descriptions of bonds or shared experiences among individuals or groups that experienced the hurricane.

4.4 Resilience\Coping

Descriptions of coping (attempts to deal with difficulties or overcome challenges).

4.4.1 Resilience\Coping\Getting on with it

A specific method of coping employed by participants that is task-oriented. rather than emotion-oriented.

4.5 Resilience\Community Resilience

Descriptions of resilience within the community. These may include descriptions of the ways that the community absorbed the disruption from the hurricane but was able to adapt to normality or to achieve collective wellbeing.

5 Danger or Emergency

Descriptions about instances in which the participant may have been in danger or experienced an emergency.

6 Good Quote

Quotes that are particularly interesting or salient.

7 Past Hurricane Experience

Mentions of experiences with past hurricanes (prior to the 2017 hurricanes).

8 Impact on Family/Friends/Relationships

Descriptions of how family, friends or relationships were impacted by the events or consequences of the hurricanes.

9 Competing Priorities

Descriptions of participants having to consider multiple needs and/or decide which need to prioritize.

10 Recommendations

Participant recommendations for improving the pre-hurricane preparedness or post-hurricane experience for pregnant women and their infants.

10.1 Recommendations\Support

Participant recommended that pregnant women receive additional support when dealing with hurricanes.

10.2 Recommendations\Future Coping Mechanisms

Participant recommended specific mechanisms for coping with pregnancy and hurricanes.

10.3 Recommendations\Information

Participant recommended additional information.

10.4 Recommendations\Leave

Participant recommended that pregnant women leave the island in the face of future hurricanes.

10.5 Recommendations\Pre-Hurricane Guidance for Pregnant Women

Participant recommended that pregnant women receive specific pre-hurricane guidance.

11 Impact of Living in a US Territory

Participants describe what impact living in a US territory may have had on their experience.

11.1 Impact of Living in a US Territory\Lack of publicity to USVI

Participant mentions that there was a lack of publicity on the USVI after the hurricanes.

12 Pregnancy and Birth

Participant descriptions of their pregnancy or birth.

12.1 Pregnancy and Birth\Left Island for Birth/Medical Care

Description of leaving the island for medical care during their pregnancy or specifically for birth.

12.2 Pregnancy and Birth\Complications

Mentions of specific complications that the participant experienced in their pregnancy or birth pre- or post-hurricane.

12.3 Pregnancy and Birth\Zika

Participant mentions Zika. This may include mentions of concerns of Zika virus infection, testing or test results, or preventing Zika virus infection.

12.4 Pregnancy and Birth\Stay or Leave

Descriptions of thoughts around staying or leaving the island before or after the Hurricanes. This may include recounting of conversations with family and friends, internal thoughts, and the decision-making process.

12.5 Pregnancy and Birth\Experience at Hospital

Descriptions of giving birth (or maternity surveillance) at the hospital.

12.5.1 Pregnancy and Birth\Experience at Hospital\Opinion of Care

Participant's personal opinion of the quality of care that they received.

12.5.2 Pregnancy and Birth\Experience at Hospital\Low Supplies

Mention of there not being enough of a particular supply or product at the hospital.

12.5.3 Pregnancy and Birth\Experience at Hospital\Hospital Damage/Condemnation

Mention of damage to the hospital or mention of the hospital being condemned.

12.6 Pregnancy and Birth\Birth

Participant description of the events of their labor, birth and postpartum.

13 Post-Hurricane

Descriptions of events of conditions after the hurricanes.

13.1 Post-Hurricane\Damage to Home

13.2 Post-Hurricane\Taking Stock

Participant descriptions of what they saw or experienced the first day after the hurricane (landscape, damage, curfew, and more).

13.3 Post-Hurricane\Employment

Descriptions surrounding their employment status and situation.

13.3.1 Post-Hurricane\Employment\Not Helpful

Participant recounts ways in which their employer, fellow employees, or supervisor were not helpful in providing information, resources or support.

13.3.2 Post-Hurricane\Employment\Helpful

Participant recounts ways in which their employer, fellow employees, or supervisor were helpful in providing information, resources or support.

13.4 Post-Hurricane\Left Island Temporarily

Descriptions of leaving the island temporarily for non-medical reasons.

13.5 Post-Hurricane\Pediatric Care

Descriptions of securing or receiving pediatric care for their infant.

13.6 Post-Hurricane\Lack of Support from Friends/family

Descriptions of not having support from family and friends after the hurricanes.

13.7 Post-Hurricane\Impact on Hours and Processes

Descriptions of ways in which the hurricanes impacted business hours and processes on the island.

13.8 Post-Hurricane\Postpartum Care

Descriptions around receiving postpartum care after the hurricanes.

13.9 Post-Hurricane\Caring for Child

Descriptions around caring for their infant after the hurricanes.

13.10 Post-Hurricane\Poor Communication

Descriptions of poor communication from businesses or the government after the hurricanes.

13.11 Post-Hurricane\Displacement

Descriptions of being displaced from their home.

13.12 Post-Hurricane\Support from Fam and Friends

Descriptions of the ways in which family and friends provided support after the hurricanes.

13.13 Post-Hurricane\Financial

Descriptions of ways in which the hurricanes impacted the finances of the participant.

13.14 Post-Hurricane\Post-Hurricane Food & Water

Descriptions of hurricane impact on access to clean water and food. This may also include descriptions of the ways in which participants secured these items.

13.15 Post-Hurricane\Lack of Electricity

Description of the hurricane's impact on electricity and descriptions of what it was like to live without electricity, or concerns around caring for newborn without electricity.

13.16 Post-Hurricane\Resources

Descriptions of resources that participants either needed, took advantage of, or wanted to take advantage of after the hurricanes.

13.16.1 Post-Hurricane\Resources\Lack of items

Specific descriptions of items that the participant needed related to pregnancy and infant care.

13.16.2 Post-Hurricane\Resources\Unable to Benefit

Descriptions of the participant's inability to benefit from a desired resource.

13.16.3 Post-Hurricane\Resources\WIC/Other Social Services

Description of use of WIC or other social services after the hurricane.

13.16.4 Post-Hurricane\Resources\Disaster Resources

Description of disaster-specific resources such as D-SNAP, FEMA issued funds for reimbursement for damaged household items, or tangible resources to aid with securing their house or roof.

13.17 Post-Hurricane\Impact on Health

Mention of the impacts the hurricanes had on their health.

13.17.1 Post-Hurricane\Impact on Health\Sought mental health therapy

Mention of seeking mental health therapy or counseling after the hurricanes.

13.17.2 Post-Hurricane\Impact on Health\Stress

Descriptions of the impact of hurricane-related stress on the participant.

13.17.2.1 Post-Hurricane\Impact on Health\Stress\In Utero Stress

Mention by the participant that they were concerned that the stress associated with the hurricane may impact the developing fetus. Also includes mention on specific attempts to reduce or control stress or emotions so as not to disturb the fetus.

13.17.3 Post-Hurricane\Impact on Health\Sadness or Depression

Descriptions of sadness or depression that the participant attributes to their experience after the hurricanes.

13.18 Post-Hurricane\Prenatal Care Post-Hurricane

Descriptions about receiving prenatal care post-hurricane.

13.18.1 Post-Hurricane\Prenatal Care Post-Hurricane\Contacting OB Office/Provider

Participant descriptions of how they contacted their OB provider to make appointments after the hurricane.

13.18.2 Post-Hurricane\Prenatal Care Post-Hurricane\Delay/Interruption in PNC

Descriptions of delays or interrupted prenatal care.

13.18.3 Post-Hurricane\Prenatal Care Post-Hurricane\Damage to OB Provider Office

Descriptions of damaged OB provider offices.

13.19 Post-Hurricane\Impact of Hurricane on Pregnancy Perception

Mention of how the hurricane impacted their perception of their pregnancy.

13.20 Post-Hurricane\What Made It Hard

Descriptions of “what made it hard” to be pregnant and deal with a hurricane simultaneously.

14 Pre-Hurricane

Descriptions of life, plans, expectations or perceptions the participant had prior to the hurricanes.

14.1 Pre-Hurricane\Wasn't going to be as bad

14.2 Pre-Hurricane\Plans for Birth

Description of pre-hurricane plan for birth.

14.3 Pre-Hurricane\Finding a Safe Place to Stay

Description of finding a safe place to stay for the night of the hurricane.

14.4 Pre-Hurricane\Expectations

Description of what the participant thought or expected pregnancy and birth to be like prior to the hurricanes.

14.5 Pre-Hurricane\Preparing

Descriptions of disaster preparations made prior to hurricane.

14.6 Pre-Hurricane\Pre-Hurricane Concerns

Descriptions of concerns that participant had about the storms in the days leading up to the hurricanes.

15 Lines

Descriptions of standing in line for resources/goods/services after the hurricane.

16 Hurricane Irma-STX or Maria-STT

Mentions of experiences with Hurricane Irma (only if they were on STX) or Hurricane Maria (only if they were on STT).

17 Night of Hurricane

Descriptions of the night of the hurricane(s).

17.1 Night of Hurricane\Damage to House

Appendix C: Time Series Analysis Regression Results

Table A1. No Prenatal Care – Final Time Series Model Results

	USVI					US				
	Coefficient	**Standard Error**	**Z Statistic**	**P-Value**	**95% CI**	**Coefficient**	**Standard Error**	**Z Statistic**	**P-Value**	**95% CI**
Intercept *b0*	5.137	5.429	0.95	0.344	(-5.504, 15.778)	-1.945	1.222	-1.59	0.111	(-4.340, 0.449)
Baseline trend *b1*	0.238	0.240	0.99	0.322	(-0.233, 0.710)	0.012	0.004	3.20	0.001	(0.005, 0.019)
Level change after hurricanes *b2*	2.513	5.028	0.5	0.617	(-7.342, 12.368)	0.002	0.029	0.06	0.952	(-0.055, 0.059)
Trend change after hurricanes *b3*	-0.628	0.417	-1.51	0.132	(-1.446, 0.189)	-0.004	0.003	1.26	0.207	(-0.010, 0.002)
Teen	0.086	0.329	0.26	0.793	(-0.559, 0.732)	0.248	0.129	1.93	0.054	(-0.005, 0.501)
AMA						0.005	0.061	0.08	0.937	(-0.114, 0.124
Hispanic						0.023	0.0259	0.89	0.373	(-0.028, 0.074)
NH Black						0.087	0.052	1.72	0.086	(-0.013, 0.192)

Table A2. No Hypertensive Disorders of Pregnancy – Final Time Series Model Results

	USVI					US				
	Coefficient	**Standard Error**	**Z Statistic**	**P-Value**	**95% CI**	**Coefficient**	**Standard Error**	**Z Statistic**	**P-Value**	**95% CI**
Intercept *b0*	2.314	1.295	1.79	0.08	(-0.290, 4.918)	2.83	4.811	0.59	0.557	(-6.605, 12.255)
Baseline trend *b1*	-0.035	0.045	-0.77	0.447	(-0.125, 0.056)	.033	0.015	2.27	0.023	(0.004, 0.062)
Level change after	1.141	1.321	0.86	0.392	-1.514, 3.797)	.050	0.155	0.32	0.746	(-0.254, 0.355)

hurricanes *b2*										
Trend change after hurricanes *b3*	0.066	0.094	0.7	0.486	(-0.124, 0.256)	.014	0.015	0.89	0.373	(-0.017, 0.045)
Teen	-0.012	0.116	-0.1	0.92	(-0.244, 0.221)	0.065	0.406	0.16	0.973	(-0.731, 0.860)
AMA						0.413	0.254	1.63	0.104	(-0.084, 0.911)
Hispanic						-0.274	0.095	-2.88	0.004	(-0.460, -0.087)
NH Black						0.188	0.170	1.10	0.270	(-0.146, 0.522)

Table A3. Preterm Birth – Final Time Series Model Results

	USVI					**US**				
	Coefficient	**Standard Error**	**Z Statistic**	**P-Value**	**95% CI**	**Coefficient**	**Standard Error**	**Z Statistic**	**P-Value**	**95% CI**
Intercept *b0*	7.462	1.837	4.06	<.001	(3.863, 11.062)	8.162	4.432	1.84	0.066	(-.524, 16.850)
Baseline trend *b1*	0.003	0.059	0.04	0.966	(-0.112, 0.118)	-0.031	0.014	-2.11	0.035	(-0.059, 0.002)
Level change after hurricanes *b2*	-1.113	1.682	-0.66	0.508	(-4.410, 2.183)	-.0326	0.124	-2.63	0.009	(-.569, -0.083)
Trend change after hurricanes *b3*	0.364	0.128	2.85	0.004	(0.114, 0.615)	.023	.0136	1.70	0.090	(-0.005, 0.053)
Teen	0.075	0.182	0.41	0.682	(-0.282, 0.432)	-0.845	0.483	-1.75	0.080	(-1.792, 0.102)
AMA						0.269	0.196	1.37	0.172	(-0.116, 0.653)
Hispanic						-0.279	-0.010	-2.88	0.004	(-0.468, -0.089)
NH Black						0.546	0.197	2.77	0.006	(0.159, 0.932)

Table A4. Cesarean Birth – Final Time Series Model Results

	USVI	**US**

	Coefficient	Standard Error	Z Statistic	P-Value	95% CI	Coefficient	Standard Error	Z Statistic	P-Value	95% CI
Intercept *b0*	27.931	3.106	8.99	0	(21.687, 34.176)	20.684	5.860	3.53	0.000	(9.199, 32.169)
Baseline trend *b1*	0.191	0.108	1.76	0.084	(-0.027, 0.409)	-0.039	0.018	-2.23	0.026	(-0.074, -0.005)
Level change after hurricanes *b2*	-2.328	3.167	-0.74	0.466	(-8.697, 4.040)	-0.398	0.288	-1.38	0.167	(-0.962, 0.167)
Trend change after hurricanes *b3*	-0.062	0.226	-0.27	0.786	(-0.517, 0.393)	-0.014	0.030	-0.47	0.638	(-.074, 0.045)
Teen	-0.161	0.277	-0.58	0.563	(-0.719, 0.396)	-1.129	0.415	-2.72	0.007	(-1.943, -0.315)
AMA						0.486	0.264	1.84	0.066	(-0.032, 1.004)
Hispanic						0.116	0.150	0.78	0.438	(-0.177, 0.409)
NH Black						0.462	0.002	2.38	0.017	(0.081, 0.843)

Table A5. Small for Gestational Age – Final Time Series Model Results

	USVI					US				
	Coefficient	Standard Error	Z Statistic	P-Value	95% CI	Coefficient	Standard Error	Z Statistic	P-Value	95% CI
Intercept *b0*	2.329	2.286	1.02	0.308	(-2.152, 6.811)	-3.25	1.708	-1.90	0.057	(-6.598, .009)
Baseline trend *b1*	0.116	0.094	1.23	0.217	(-0.068, 0.300)	0.002	0.007	0.25	0.800	(-.012, 0.016)
Level change after hurricanes *b2*	1.714	1.865	0.92	0.358	(-1.941, 5.370)	-0.039	0.063	-0.62	0.536	(-0.163, 0.085)
Trend change after hurricanes *b3*	-0.347	0.167	-2.08	0.037	(-0.674, -0.020)	-0.011	0.007	-1.50	0.134	(-0.025, 0.003)

Teen	-0.007	0.121	-0.06	0.955	(-0.245, 0.231)	0.570	0.154	3.71	<0.001	(0.268, 0 .871)
AMA						0.240	0.086	2.77	0.006	(0.070, 0.409)
Hispanic						0.165	0.037	4.40	0.000	(0.091, 0.238)
NH Black						0.051	0.074	0.70	0.487	(-0.093, 0.195)

Table A6. Low Birth Weight – Final Time Series Model Results

	USVI					**US**				
	Coefficient	**Standard Error**	**Z Statistic**	**P-Value**	**95% CI**	**Coefficient**	**Standard Error**	**Z Statistic**	**P-Value**	**95% CI**
Intercept *b0*	4.976	1.635	3.04	0.004	(1.675, 8.276)	1.473	1.71	0.86	0.389	(-1.878, 4.823)
Baseline trend *b1*	0.007	0.055	0.13	0.898	(-0.104, 0.119)	-.026	0.008	-3.17	0.002	(-0.043, -0.010)
Level change after hurricanes *b2*	0.358	1.829	0.2	0.846	(-3.333, 4.049)	-.183	0.071	-2.58	0.010	(-0.322, -0.044)
Trend change after hurricanes *b3*	0.057	0.178	0.32	0.75	(-0.302, 0.415)	0.010	0.008	1.18	0.236	(-0.006, 0.026)
Teen	-0.053	0.149	-0.36	0.723	(-0.355, 0.248)	-0.336	0.229	. -1.46	0.143	(-0.785, 0.113)
AMA						0.394	0.087	4.53	0.000	(0.224, 0.564)
Hispanic						-0.111	0.047	-2.39	0.017	(-0.204, 0.020)
NH Black						0.312	0.093	3.37	0.001	(0.131, 0.494)

CURRICULUM VITAE

PERSONAL DATA

Name: Noelene K. Jeffers, MSN, CNM, IBCLC
DOB: September 1, 1984
Location of Birth: St. Croix, USVI
Address: 525 N. Wolfe Street, Baltimore, MD 21205
Phone: (240) 521-4070
Email: **njeffer4@jhmi.edu**

EDUCATION

Years	Degree/Coursework	Institution
Aug 2017 – Present	PhD Candidate	Johns Hopkins School of Nursing Baltimore, MD
2012	Master of Science in Nursing	Yale School of Nursing New Haven, CT
June 2007 – Aug 2008	Pre-Health Sciences Post-Baccalaureate Coursework	Rutgers University
May 2006	Bachelor of Science in Foreign Service	Georgetown University Washington, DC

CURRENT LICENSURE AND CERTIFICATION

Years	Source	Type
2012 – 2020	District of Columbia	Certified Nurse Midwife Advanced Practice Registered Nurse
2014 – 2019	International Board of Lactation Consultant Examiners	International Board Certified Lactation Consultant
2012 – 2022	American Midwifery Certification Board	Certified Nurse Midwife

PROFESSIONAL EXPERIENCE

Years	Position	Institution/Location
2018 -	Instructor, Nurse-Midwifery/WHNP Program	Georgetown University Washington DC
2016 -	Clinical Faculty Advisor, Nurse-Midwifery/WHNP Program	Georgetown University Washington DC
2014 -	Certified Nurse Midwife	Unity Healthcare Washington, DC
2017	Per-Diem Certified Nurse	Providence Hospital

	Midwife	Washington DC
2016 – 2018	Adjunct Clinical Instructor	A.T. Still University School of Osteopathic Medicine – Unity Healthcare Campus Washington, DC
2014	Interim Director of Midwifery	Community of Hope Family Health and Birth Center Washington, DC
2012 – 2014	Certified Nurse Midwife	Community of Hope Family Health and Birth Center Washington, DC
2011	Teaching Associate, Medical-Surgical and Maternal Newborn Nursing	Yale University School of Nursing New Haven, CT
2010	Registered Nurse	Mollen Immunizations
2010	Registered Nurse	Kingsley Pines Camp
2008	Associate Project Manager	Maxcess Managed Markets
2007 – 2008	Project Manager	Braun Research
2006 – 2007	Policy Analyst	Apprise, Inc.

HONORS AND AWARDS

Years	Honors/Awards	Institution/Location
2019	Cynthia Davis Sculco Scholarship	Nurses Educational Funds, Inc.
2019	Research Award	Sigma Theta Tau – Nu Beta Chapter
2019	Graduate Nursing Scholarship	March of Dimes
2017	Future of Nursing Scholar	Robert Wood Johnson Foundation
2014	Leadership Development Award	American College of Nurse Midwives
2012	Sigma Theta Tau – Delta Mu Chapter	Yale University
2009	Helene Fuld Trust Scholarship	Yale University
2009	Elizabeth Rodd Merit Scholarship	Yale University
2006	Honorable Mention, Dean's Citation	Georgetown University
2005-2006	Junior Fellow	Institute for the Study of Diplomacy Georgetown University
2005	Public Policy and International Affairs Fellowship	University of Michigan Ford School of Public Policy

2004	Scholar, Peter F. Krogh Honors Program	Georgetown University

RESEARCH

Years	Research Activities	Project
March 2019 - present	Literature review. Manuscript development.	Neighborhood Segregation and Prenatal Care Access and Utilization
October 2018 – present	Interview coding Manuscript development.	HIV-prevention and PrEP promotion strategies among IPV exposed women
October 2017 – July 2018	In-depth interview coding. Manuscript development.	Reproductive coercion and pregnancy intention among low-income Latina women
May 2006 – June 2007	Survey project management.	PGW Customer Survey Services Evaluation
May 2006 – June 2007	Direct service observations. In-depth interviews and analysis.	Verizon Communications Lifeline Program Evaluation
May 2006 – June 2007	Survey management.	Evaluation of PECO's Universal Services Programs
May 2006 – June 2007	In-depth interviews and analysis. Survey project management.	Evaluation of the Colorado REACH Evaporative Cooler Program
May 2006 – June 2007	In-depth interviews and analysis.	Evaluation of the We Energies Commercial and Industrial Energy Efficiency Program

PRACTICE

Instructor. Five-day course in Jamaica for nurses and physicians in the Caribbean about caring for women experiencing violence. Funder: PAHO/WHO. *June 2019.*

Instructor. Five-day course for nurse auxiliaries focused on providing prenatal, intrapartum, and postpartum care for women in a clinic and birth center run by the Petite Soeurs de Sainte Thérèse in Haiti. Funder: Medecines for Humanity. *July 2016.*

SCHOLARSHIP

Peer-reviewed Publications

Jeffers, N.K. (2015). My Nipples Hurt: Could I have Raynaud's? *Journal of Human Lactation,* 31(4), 675-676. https://doi.org/10.1177/0890334415597902

Grace, K. T., Alexander, K. A., **Jeffers, N. K.,** Miller, E., Decker, M. R., Campbell, J., & Glass, N. (2020). Experiences of Reproductive Coercion Among Latina Women and Strategies for Minimizing Harm: "The Path Makes Us Strong". *Journal of Midwifery & Women's Health.* Advance online publication. https://doi.org/10.1111/jmwh.13061

Bryant, A., Riley, L., Neale, D., Hill, W., Jones, T.B., **Jeffers, N.K.,** Loftman, P., Clare, C.A., Gudeman, J. Communicating with African-American women who have had a preterm birth about risks for future preterm births. *Journal of Racial and Ethnic Health Disparities.* Advance online publication. https://doi-org.proxy1.library.jhu.edu/10.1007/s40615-020-00697-8

Manuscripts in Progress

Jeffers, N.K. Pregnancy and birth outcomes following hurricane exposure: An integrative review. *Journal of Obstetric, Gynecologic and Neonatal Nurses: JOGNN.* ***(In Review).***

Jeffers, N. K., Celius, L., Willie, T. C., Kershaw, T. S. & Alexander, K. (2019, November). *'Connecting the dots': Provider Perspectives about strategies for HIV pre-exposure prophylaxis (PrEP) awareness, uptake, adherence and retention among women exposed to intimate partner violence. (In Preparation).*

Jeffers, N. K., Celius, L., Willie, T. C., Kershaw, T. S. & Alexander, K. (2019, November). *'Planting the seed': The provider perspective on strategies for HIV prevention among IPV exposed women. (In Preparation).*

Zemlak, J., Jeffers, N. K., Bryant, A. A Systematic Review of Contraceptive Use Among Sex Workers in North America. ***(In Review).***

Published Abstracts

Grace, K.T., Alexander, K.A., **Jeffers, N. K.,** Miller, E., Decker, M.R., Campbell, J. & Glass, N.E. (2019). The path makes us strong: Experiences of reproductive coercion among Latina women and strategies for minimizing harm. *Journal of Midwifery and Women's Health, 64*(5), 675. https://doi.org/10.1111/jmwh.13055

Posters/Presentations

Jeffers, N. K., Celius, L., Willie, T. C., Kershaw, T. S. & Alexander, K. (2019, November). *'If the partner finds out, then there's trouble': Provider perspectives on safety planning and partner interference when offering HIV pre-exposure prophylaxis to women experiencing intimate partner violence.* Podium presentation at the Association of Nurses in AIDS Care Conference, Portland, OR.

Jeffers, N. K., Celius, L., Willie, T. C., Kershaw, T. S. & Alexander, K. (2019, November). *'Connecting the dots': Provider Perspectives about strategies for HIV pre-exposure prophylaxis (PrEP) awareness, uptake, adherence and retention among women exposed to intimate partner violence.* Podium presentation at the Association of Nurses in AIDS Care Conference, Portland, OR.

Jeffers, N. K., Celius, L., Willie, T. C., Kershaw, T. S. & Alexander, K. (2019, November). *'Planting the seed': The provider perspective on strategies for HIV prevention among IPV exposed women.* Poster presentation at the American Public Health Association Meeting, Philadelphia, PA.

Grace, K.T., Alexander, K.A., **Jeffers, N. K.,** Miller, E., Decker, M.R., Campbell, J. & Glass, N.E. (2019, May). *The path makes us strong: Experiences of reproductive coercion among Latina women and strategies for minimizing harm.* Podium presentation at American College of Nurse Midwives 64th Annual Meeting, Washington, DC. Presentation conducted by Grace, K.T.

Grace, K.T., Alexander, K.A., **Jeffers, N. K.,** Miller, E., Decker, M.R., Campbell, J. & Glass, N.E. (2019, May). *The path makes us strong: Experiences of reproductive coercion among Latina women and strategies for minimizing harm.* Podium Presentation at the 2019 Society for Nursing Research Conference. Presentation conducted by Grace, K.T.

Jeffers, N.K. (2019, May). *Birth outcomes following hurricane exposure: An integrative review.* Poster presented at the American College of Nurse Midwives 64th Annual Meeting, Washington DC.

Jeffers, N.K. (2019, May). *Toward maternal-infant health equity and justice: The agenda for midwifery practice, education and research.* Podium presentation at the American College of Nurse Midwives 64th Annual Meeting, Washington DC.

Grace, K.T., Alexander, K.A., Miller, E., **Jeffers, N.K.,** & Glass, N.E. (2018, May). *Reproductive coercion and pregnancy intention among low-income Latina women: A qualitative analysis.* Poster presentation at American College of Nurse Midwives 63rd Annual Meeting, Savannah, GA.

Loftman, P., **Jeffers, N.K.,** Peterson, S., Gudeman, J., Bryant, A. (2018, May). *Communicating with African-American mothers about the risks for recurrent preterm births.* Poster presentation at the American College of Nurse Midwives 63rd Annual Meeting, Savannah, GA

Jeffers, N. K. (2015, October). *Peace to the perineum: Introduction to repair of first- and second-degree perineal lacerations.* Conference workshop presented at the Black Midwives and Healers Conference, Portland, OR.

Jeffers, N. K. (2012, May). *Normal birth: A concept analysis.* Paper presented at the meeting of the ACNM Connecticut Affiliate, New Haven CT.

PROFESSIONAL ACTIVITIES

DC Breastfeeding Commission
- 2017 – present, Appointed Commissioner

National Association to Advance Black Birth (NAABB)
- 2018 – present, Member, Board of Directors
- 2015 – 2017, President and Chair, Board of Directors

Sigma Theta Tau International
- 2012 – present, Member, Delta Mu Chapter

American College of Nurse Midwives
- 2018 – 2019, Member, ACNM Diversity and Inclusion Committee
- 2017 – 2019, Gender Equity Task Force, Member
- 2017 – 2018, Member, ACNM Task Force to Address Bias and Discrimination
- 2016 – 2018, Member, Students and New Midwives Section

US Midwifery Education Regulation Association
- 2016 – present, Member, Steering Committee

American College of Nurse Midwives, District of Columbia Affiliate
- 2012 – present, Member

National Academy of Medicine Leadership Consortium
- 2015 – Present, Care Culture and Decision-Making Innovation and Collaborative Roundtable

National Institute of Child Health and Human Development
- 2014 – Participant, Safe to Sleep Breastfeeding Outreach Meeting

International Lactation Consultant Association
- 2014 – 2016, Member

US Lactation Consultant Association
- 2014 – 2015, Member

EDUCATIONAL ACTIVITIES

Classroom Instruction *(May 2018, NURO510 Introduction to Reproductive Health Care of Women, Adjunct Instructor, 9 enrolled students)*

Classroom Instruction *(September 2018, NURO510 Introduction to Reproductive Health Care of Women, Adjunct Instructor, 13 enrolled students)*

Classroom Instruction *(January 2019, NURO510 Introduction to Reproductive Health Care of Women, Adjunct Instructor, 12 enrolled students)*

Classroom Instruction *(May 2019, NURO510 Introduction to Reproductive Health Care of Women, Adjunct Instructor, 14 enrolled students)*

Classroom Instruction *(September 2019, NURO510 Introduction to Reproductive Health Care of Women, Adjunct Instructor, 13 enrolled students)*

Classroom Instruction and Course Coordination *(January 2020, NURO733 Advanced Seminars in Women's Health, Instructor, 36 enrolled students)*

ACADEMIC SERVICE

Retention Task Force
Committee for Curriculum and Instruction
Georgetown University, School of Nursing & Health Studies

MENTORING

Georgetown Scholarship Program *(2015-2018)*